VOL. XXVII. — No. 3. MARCH 1950.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

THE LIBRARY OF THE
UNIVERSITY OF ILLINOIS

Digitized by the Internet Archive
in 2024

https://archive.org/details/rail-international_1950-03_27_3

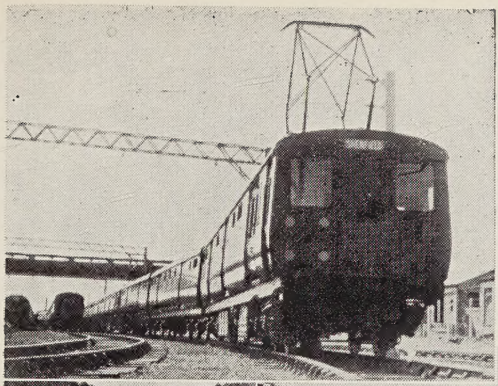
VERSATILITY

There is

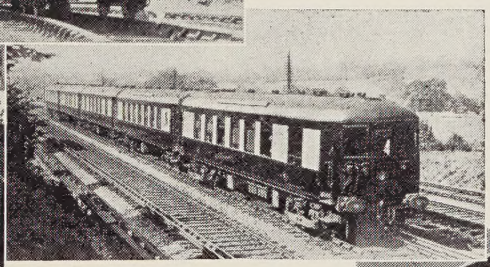
WESTINGHOUSE

BRAKING

suitable for any type of railway rolling stock, from the fast passenger or long heavy freight train to the single unit rail coach.



1

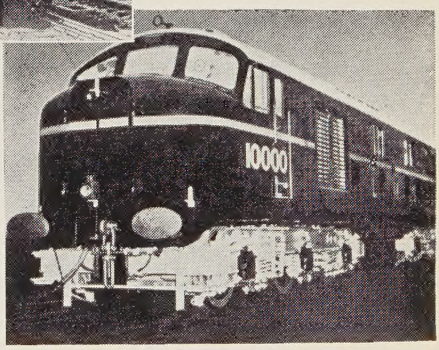


2

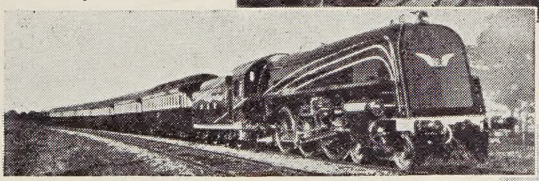
5

4

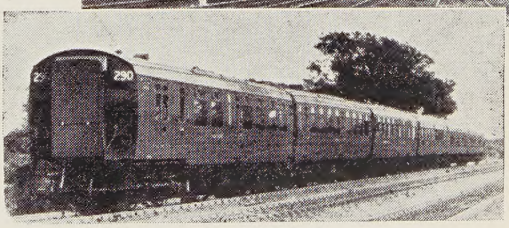
6



3



7



8

AIR BRAKES
VACUUM BRAKES
ELECTRO-PNEUMATIC BRAKES

●

1 Self-lapping electro-pneumatic.
2 Automatic Air.
3 Vacuum Brake with Air Equipment.
4 Straight Air with Emergency.
5 Lu Type Automatic for empty-load, passenger-freight.
6 6 E. T. Locomotive brake for passenger, freight or shunting.
7 Air and vacuum for electric locomotives for passenger or goods.
8 Automatic vacuum.

Photos. by Courtesy of British Railways, Eastern Region (1), Southern Region (2, 7, 8), Midland Region (3), Polish State Railways (5), Hunslet Engine Co. Ltd. (4), South Australian Govt. Rlys. (6).

WESTINGHOUSE BRAKE & SIGNAL CO. LTD., 82, York Way, King's Cross, London, N.1

SEVENTY-FOUR YEARS OF BRAKING

« ATHERMOS »

IN THE WORLD

MORE THAN

625.000

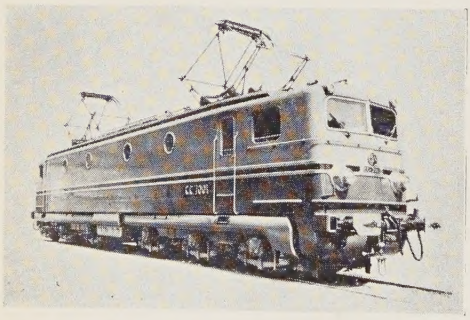
AXLEBOXES WITH MECHANICAL LUBRICATION

« ISOTHERMOS SYSTEM »

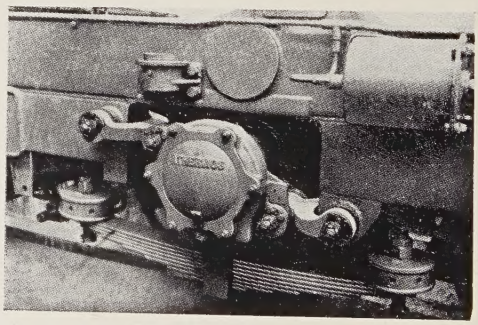
ARE IN SERVICE

(Electric and Diesel-electric locomotives, tenders, coaches, wagons, etc.)

Saving
Safety
Easiness of fitting and maintenance



S. N. C. F. electric locomotive C. C. nº 7001 equipped with « ATHERMOS » type axleboxes (ISOTHERMOS latest model)



S. N. C. F. electric locomotive C. C. nº 7001 Details of the suspension

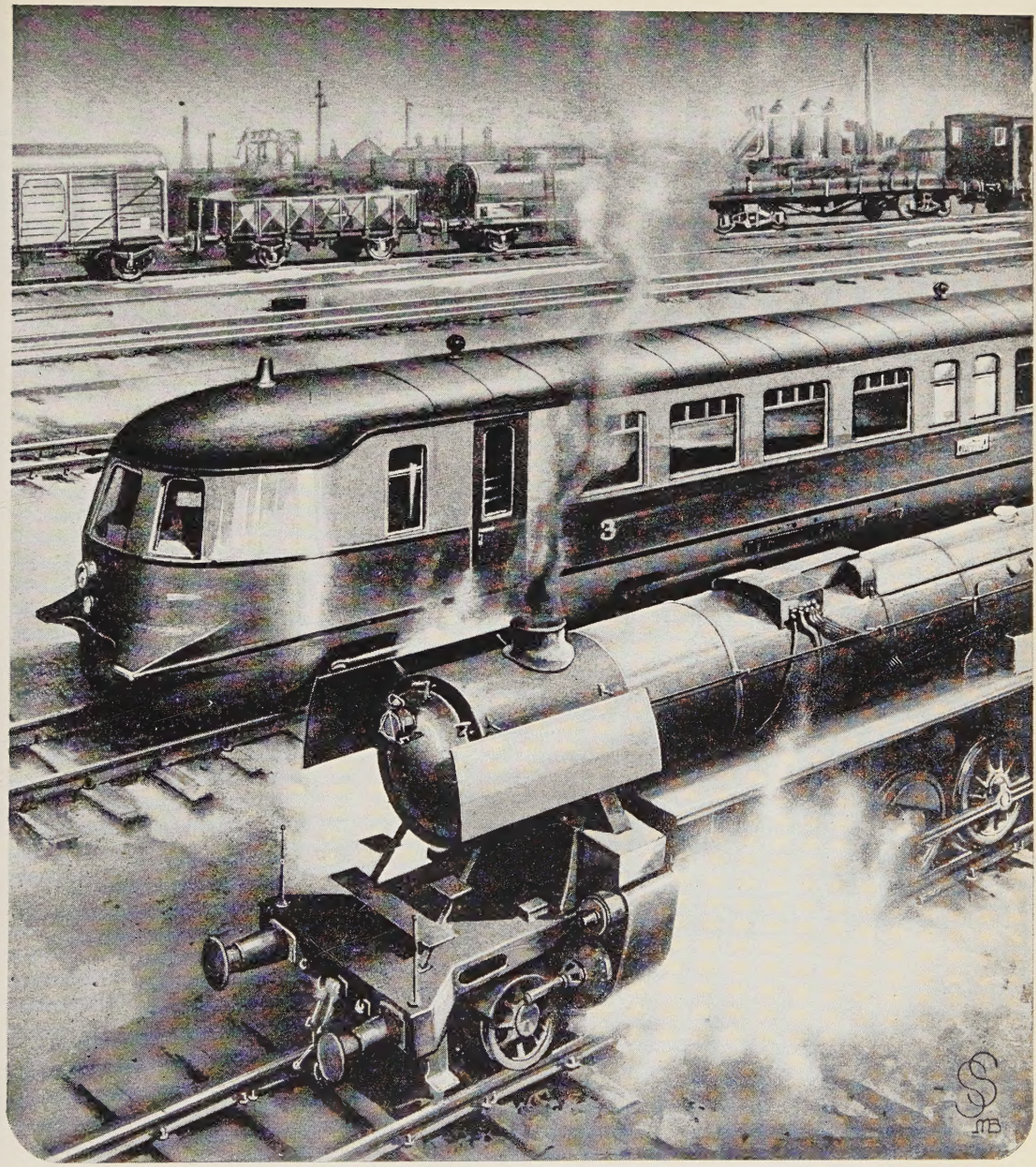
Sociétés Générales Isothermos

35, rue de la Tour d'Auvergne, PARIS (9e)

9, rue du Moniteur, BRUSSELS

Société Internationale des Applications Isothermos

60, avenue de la Grande Armée, PARIS (17e)



RAILWAY AND TRAMWAY ROLLING STOCK

Ste ANGLO-FRANCO-BELGE

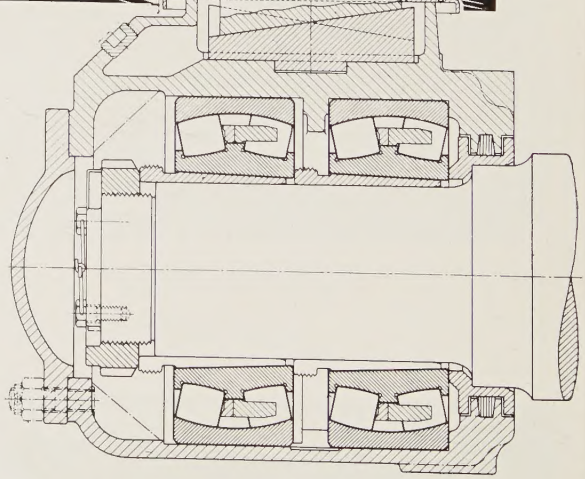
DES ATELIERS DE LA CROYÈRE, SENEFFE ET GODARVILLE, S. A.

Head Office : LA CROYÈRE · Belgium

Telegrams : LOCOMORAM — LA CROYÈRE — Téléphone LA LOUVIÈRE Nos 44 et 829.

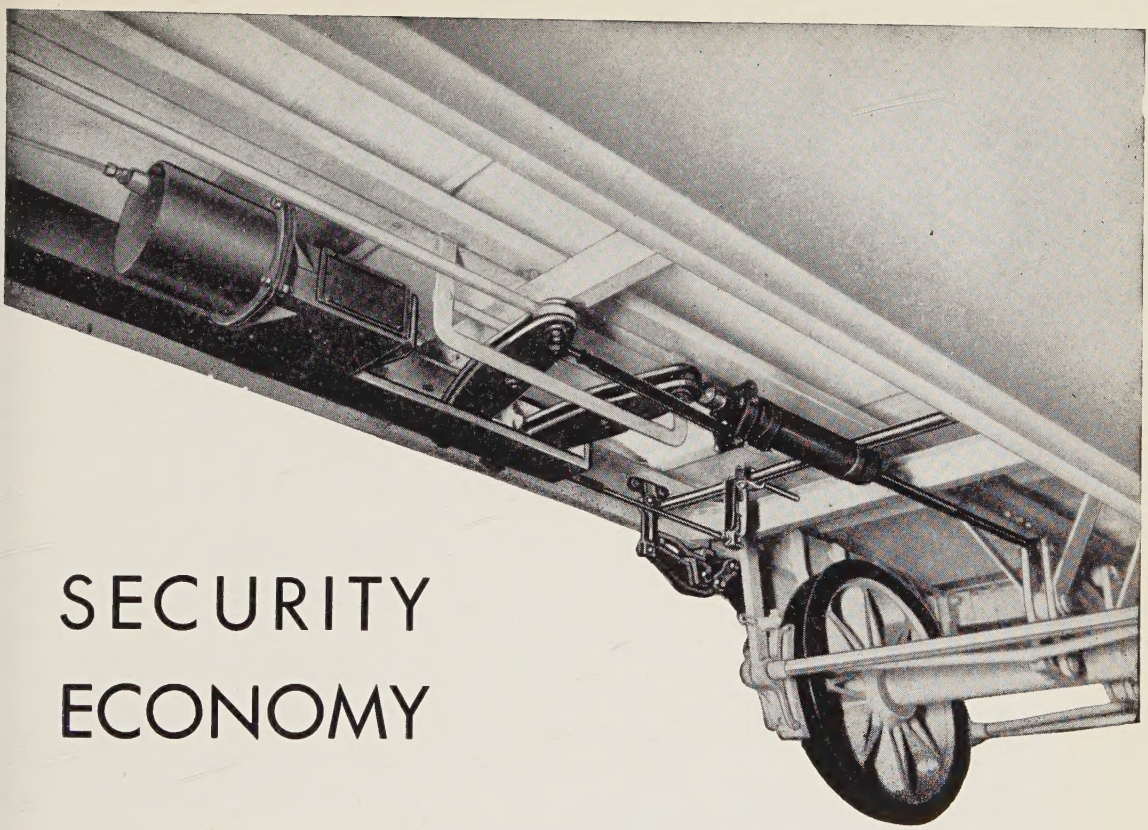
SKF
SELF-ALIGNING ROLLER-BEARING AXLEBOXES
promote reliability

The Swedish State Railways' new F-Series electric locomotives reaching a maximum speed of 135 km./hr. have **SKF** self-aligning roller-bearings on all driving and free axles. The four motors of together 3,500 h. p. are equipped with **SKF** cylindrical-roller bearings.



- Reliability, even at the highest speeds — no hot bearings.
- Saving of lubricant and of labour for lubrication.
- Lower maintenance expenses.

SKF



SECURITY
ECONOMY

SAB

BRAKE REGULATOR TYPE DR

with double rapid action

CONTINUOUS LOAD BRAKE ADAPTER TYPE AC

for braking power proportional to the load

SVENSKA AKTIEBOLAGET BROMSREGULATOR

Adelgatan 5, Malmö, Sweden

S. A. LA BRUGEOISE et NICAISE & DELCUVE

Steel-works, Forges and Engineering Works

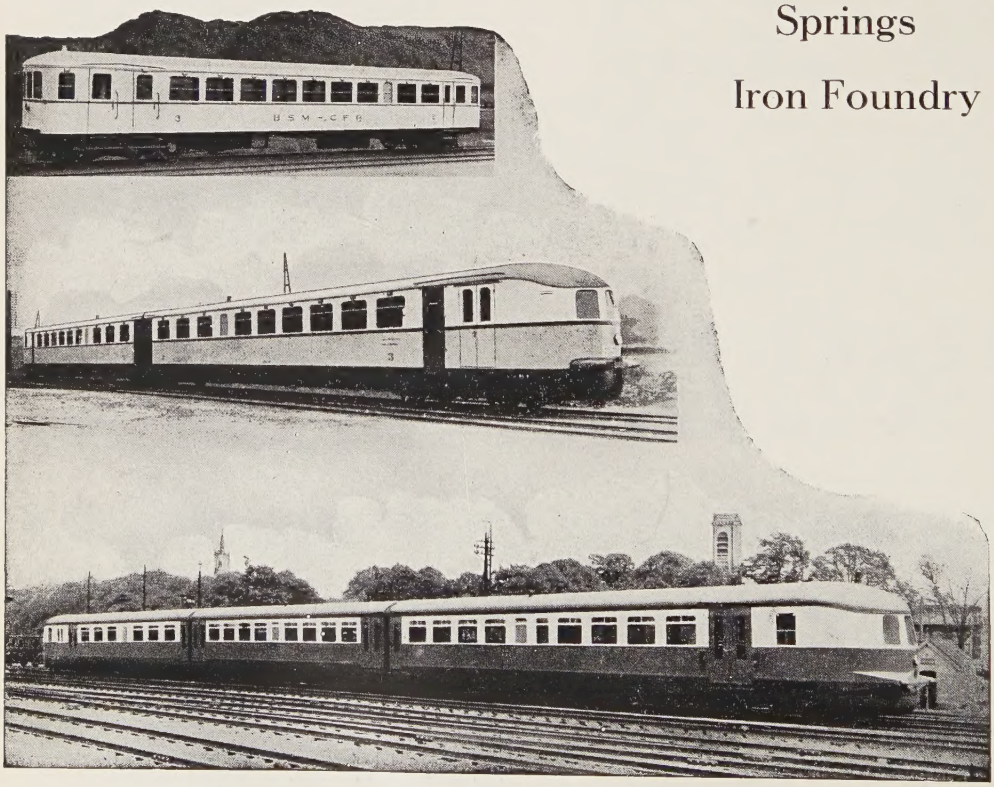
Works at St-Michel near Bruges and at La Louvière (Belgium)
General Management at St-Michel near Bruges

Rolling Stock and Fixed Equipment for Railways and Tramways

Bridges, Frames, Tanks
and all Metallic Constructions riveted and welded
Steel Castings of all kinds and qualities

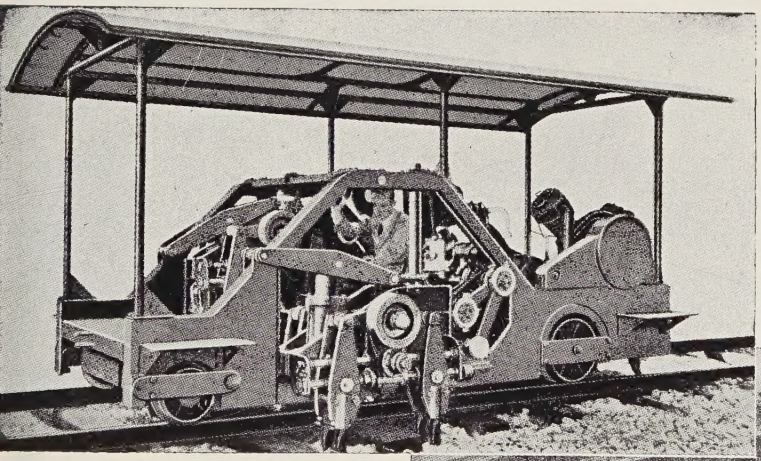
Springs

Iron Foundry



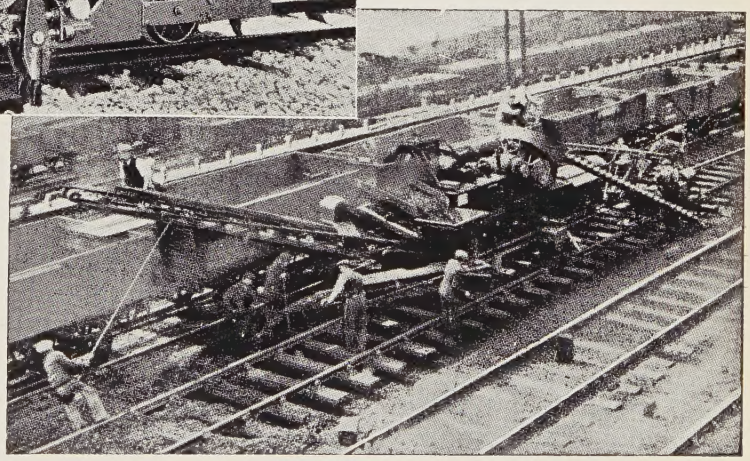
HIGH EFFICIENCY

PERMANENT WAY EQUIPMENT



AUTOMATIC
TAMPING MACHINE

16 tamping tools actuated simultaneously complete the ballast packing of each sleeper in one operation.
The machine can be side tracked in one minute.

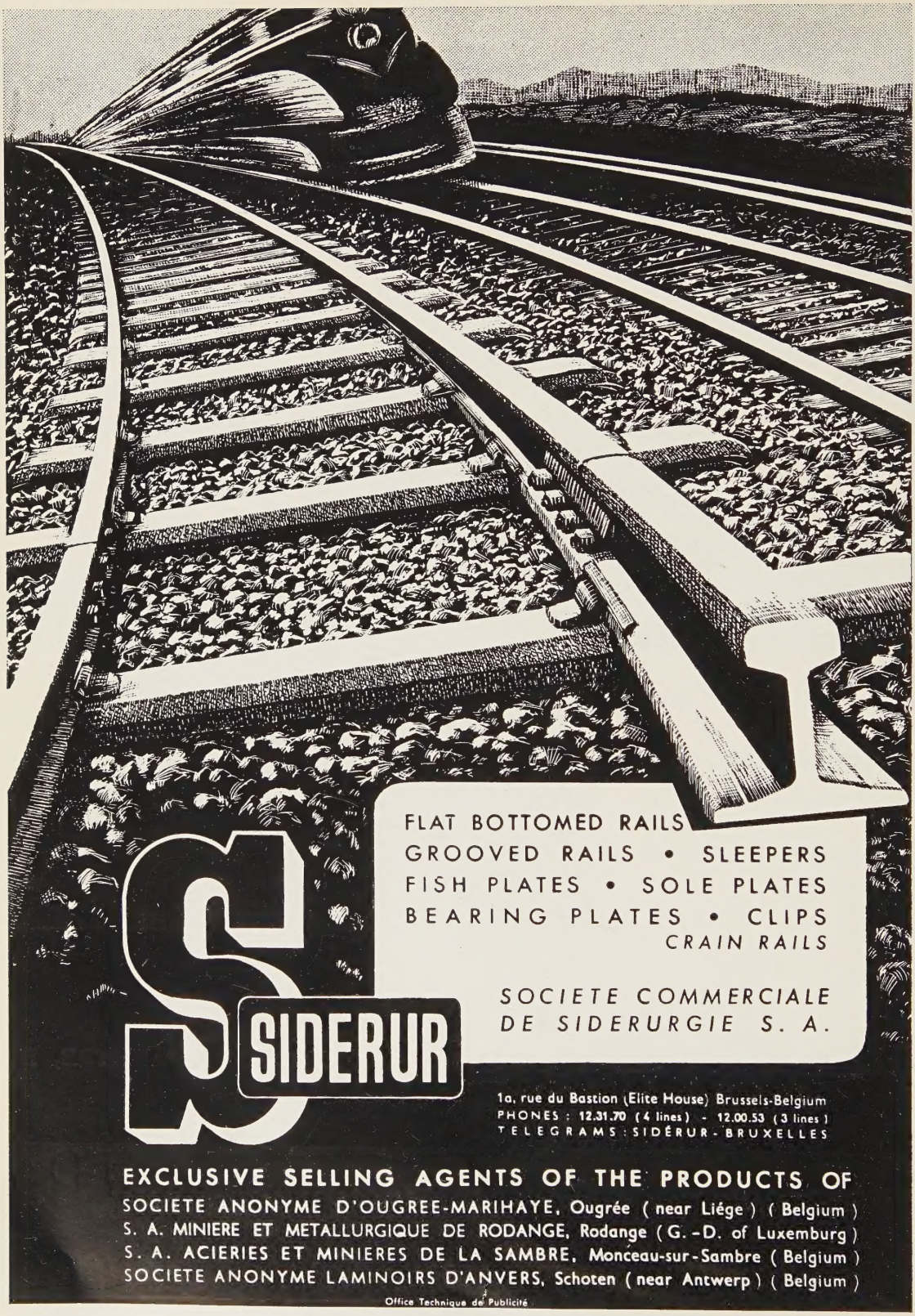


AUTOMATIC BALLAST
CLEANER

The machine can be side tracked in a few minutes.

SLEEPER SCREW DRIVING MACHINES - RAIL SAWS AND DRILLS - SLEEPER DRILLS
CALCULATOR FOR THE ADJUSTMENT OF CURVES - RIPAMETRE, ETC.

MATISA EQUIPMENT LIMITED
LONDON, 78, Buckingham Gate, Westminster, S. W. 1
Licensees from MATERIEL INDUSTRIEL S. A. LAUSANNE. Switzerland
Agents and representatives in
PARIS, CHICAGO, BUENOS AIRES, RIO DE JANEIRO, ADELAIDE, CAPETOWN, etc.


FLAT BOTTOMED RAILS
GROOVED RAILS • SLEEPERS
FISH PLATES • SOLE PLATES
BEARING PLATES • CLIPS
CRAIN RAILS
SOCIETE COMMERCIALE
DE SIDERURGIE S. A.
SIDERUR
1a, rue du Bastion (Elite House) Brussels-Belgium
PHONES : 12.31.70 (4 lines) - 12.00.53 (3 lines)
TELEGRAMS : SIDÉRUR - BRUXELLES
EXCLUSIVE SELLING AGENTS OF THE PRODUCTS OF
SOCIETE ANONYME D'OUGREE-MARIHAYE, Ougrée (near Liége) (Belgium)
S. A. MINIERE ET METALLURGIQUE DE RODANGE, Rodange (G.-D. of Luxemburg)
S. A. ACIERIES ET MINIERES DE LA SAMBRE, Monceau-sur-Sambre (Belgium)
SOCIETE ANONYME LAMINOIRS D'ANVERS, Schoten (near Antwerp) (Belgium)
Office Technique de Publicité

Bulletin of the International Railway Congress Association

CONTENTS OF THE NUMBER FOR MARCH 1950

1950 **625** .143 .4

Bull. of the Int. Ry. Congress Ass^on^, No. 3, March, p. 167.

RENDA (B.). — **Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.** (Question II, 15th Congress). Report *(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Jugoslavia, Portugal and Colonies, Rumania, Spain, Sweden and Turkey)*. (10 000 words, tables & fig.)

1950 **625** .143. 4

Bull. of the Int. Ry. Congress Ass^on^, No. 3, March, p. 207.

CROOM-JOHNSON (P.). — **Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.** (Question II, 15th Congress). Report *(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan)*. (10 000 words, tables & fig.)

1950 **656** .25

Bull. of the Int. Ry. Congress Ass^on^, No. 3, March, p. 247.

DYER (H. H.). — **Modern safety and signal installations (centralising apparatus for block system and signals). — Central electric apparatus with individual levers and « all relay » levers (all electric interlocking). — Automatic block-system with continuous current and coded current. — Light and speed signalling.** (Question IX, 15th Congress). Report *(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan)*. (6 000 words.)

1950 **624 & 691**

Bull. of the Int. Ry. Congress Ass^on^, No. 3, March, p. 259.

DEAN (A.). — **Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.** (Question I, 15th Congress). Report *(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan)*. (18 000 words, tables & fig.)

MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES : 19, RUE DU BEAU-SITE, BRUSSELS

Yearly subscription for 1950 : { Belgium . . . . . 700 Belgian Francs / Universal Postal Union. . . 800 Belgian Francs

Price of this single copy : 125 Belgian Francs. (not including postage)

Subscriptions and orders for single copies (January 1931 and later editions) to be addressed to the General Secretary, International Railway Congress Association, 19, rue du Beau-Site, Brussels (Belgium).

Orders for copies previous to January 1931 should be addressed to Messrs. Weissenbruch & Co. Ltd., Printers, 49, rue du Poinçon, Brussels.

Advertisements : All communications should be addressed to the Association, **19, rue du Beau-Site, Brussels.**

CONTENTS OF THE NUMBER FOR MARCH 1950.

CONTENTS.	Page.
I. **Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.** (Question II, 15th Congress). Report *(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Jugoslavia, Portugal and Colonies, Rumania, Spain, Sweden and Turkey)*, by B. RENDA	167
II. **Rail-joints : Improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.** (Question II, 15th Congress). Report *(America (North and South), Burma, China, Egypt, Great Britain and Northern Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan)*, by P. CROOM-JOHNSON	207
III. **Modern safety and signal installations (centralising apparatus for block system and signals). — Central electric apparatus with individual levers and « all relay » levers (all electric interlocking). — Automatic block-system with continuous current and coded current. Light and speed signalling.** (Question IX, 15th Congress), Report *(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan)*, by H. H. DYER	247

CONTENTS *(continued)*. Page.

IV. **Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.** (Question I, 15th Congress). Report *(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan)*, by A. DEAN 259

LIBRARY

OF THE

Permanent Commission of the International Railway Congress Association

READING ROOM : **19, rue du Beau-Site, Brussels.**

Works in connection with railway matters, which are presented to the Permanent Commission are mentioned in the « Bulletin ». They are filed and placed in the library. If the Executive Committee deems it advisable they are made the subject of a special notice. Books and publications placed in the reading room may be consulted by any person in possession of an introduction delivered by a member of the Association. Books, etc., may not be taken away except by special permission of the Executive Committee.

The Permanent Commission of the Association is not responsible for the opinions expressed in the articles published in the Bulletin.

All original articles and papers published in the Bulletin are copyright, except with the consent of the Authors and the Committee.

An edition in French is also published.

Vol. XXVII. — No. 3. March 1950.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .143 .4]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION II.

Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.

REPORT

(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Jugoslavia, Portugal and Colonies, Rumania, Spain, Sweden and Turkey),

by B. Renda,

Ingénieur, Inspecteur en Chef supérieur au Service de la voie des Chemins de fer Italiens de l'Etat, Rome.

BASIS OF THE REPORT.

The object of the present report is :

firstly to give the improvements recently made in the fishplating and the joint in general on up to date lines on which this subject has been studied since about 1946; as well as the results obtained in making and maintaining the fishplating;

secondly, to sum up the steps now being taken by certain Railways as regards the use as a *standard practice* of 30 to 50 m (98′ 5 1/8″ to 164′ 1/2″) welded lengths of rail, including the regulations concerning the joint gaps; as well as a summary of the special trials of longer rails laid on the running line in the open during the last few years.

SOURCES OF INFORMATION.

In August 1949, an agreed questionnaire was sent to twenty-two Railway Administrations in the countries enumerated above.

Five of these Railways replied, and the present report has been drawn up on the basis of the information received.

***

PART I.

Rail-joints. — Improvements in fishplated joints.

1. *Give the characteristics of the rail or rails in question. Drawings of the profile with the main dimensions, weight per lineal metre.*

1. Table I gives the profiles with the main dimensions of the Vignoles rails used in the up to date lines of the most important Railways.

Nearly all the Administrations use rails

TABL

Types of ra

Administration	Type of rails	Dimensions of the rail											
		Height mm	Width			Cant			Curvature of the running surface mm		*a*	*b*	*b'*
			of the foot mm	of the head mm	of the web mm	on the fishplating bearing		of the head					
Railways :		H	B	A	C	I	I_2	I_2	R	*r*	mm	mm	mm
AUSTRIA : *Federal*	FORM B (S 49)	148	125	67-70	14	1 : 3	1 : 3	1 : 16	400	14	46	165	—
	FS. P. 46.3	145	135	65	14	1 : 4	1 : 4	Vertic.	250	14	50.5	110	—
ITALY : *State*	FS. P. 50.6	149	135	65	16	1 : 4	1 : 4	Vertic.	250	14	50.5	110	—
	TIPO 49	148	125	67-70	14	1 : 3	1 : 3	1 : 16	400	14	46.5	165	—
PORTUGAL: *Portuguese Cy*	45	144	134	60	15	1 : 2	1 : 2	Vertic.	Plane	15	82	115	—
SWEDEN : *State*	Rail 1940 Mod. ARS	155	133	70-72	14	1 : 3	1 : 3	1 : 23	200	14	52.5	200	—
	Rail AV 1924 ARS	133	133	69-70	14	1:2.73	1 : 3.63	1 : 33	152	13	52.5 53.5	150	—
SWEDEN : *Private*	43.2	133	133	69-70	14	1:2.73	1 : 3.63	1 : 33	152	13	52.5	150	15

leeper spacing.

Head			Weight per metre	Rail section	Method of calculating the rails	Maximum stress allowed for the rails	Modulus of resistance	Moment of inertia	Standard length	Sleeper spacing			
										A	B	C	D
d	∅	Number of holes					W	Jx	L				
mm	mm		kg	cm²		kg/cm²	cm³	cm⁴	m	mm	mm	mm	mm
85.5	30 33	2	49.05	62.48	—	—	239	1797	30	260	546	650	650
82.5	32	2	46.5	59.26	Zimmermann	3000	217.3	1663.7	18 36	240	602.5 508.5	630 600	630 610
84.5	32	2	50.5	64.79	Zimmermann	3000	236.4	1894.5	18 36	240	602.5 508.5	630 600	630 610
85.5	29	2	49.05	62.48	Verein Mitteleuropäischer Eisenbahnverwaltungen.	3000	239	1797	18 36	260	550	575	657
79	30	2	45.125	57.85	—	—	203	1571	8-12-18	490	—	—	—
88	32	2	50	63.70	—	—	258	2046	7 ÷ 30	250	535	570 522 530	650 658 660
78	30 29	2	43.2	55	—	—	189	1310	9-10-14-20	250 250 0	535 535 430	715 570 660	750 650 660
78	30	3	43.2	55	—	—	189	1310	20 20+20=40	0	425	770	770

weighing 45 to 50 kg (99 to 110 lbs) per lineal metre. However there is a tendency to increase the weight to 50 kg in view of the increase in the axle weights and the higher train speeds.

The dimensions of the Vignoles rails are as follows :

2. *State the kind of sleeper (wood or metal) and the arrangement at joints. Is the joint carried on a single sleeper? On sleeper assemblies? Overhanging?*

2. Most of the railways use joints laid on wood sleepers (Fig. 1, 2, 3, 4, 5, 6, 7 and 8).

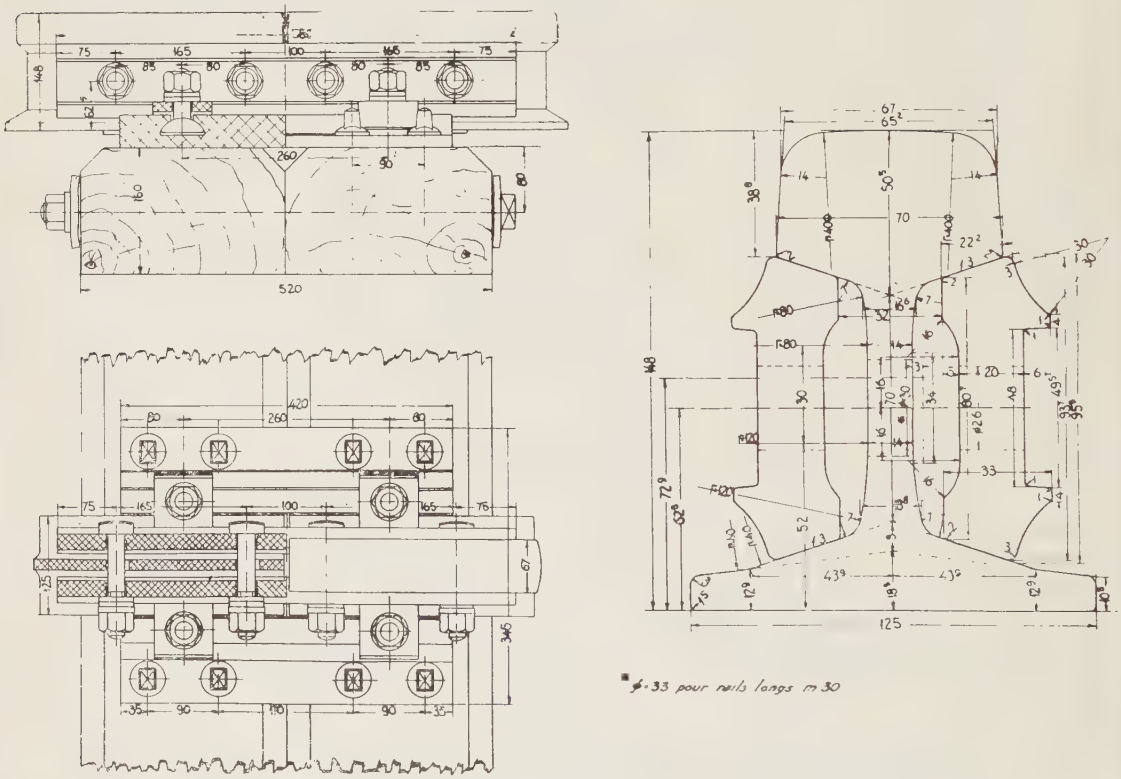


Fig. 1. — *Austrian Federal Railways.*
FORM B (S. 49) type of rail. — Joint carried on wood sleepers with indirect fastenings.

— the foot between 125 and 135 mm (4.92 and 5.31 in.);

— the head between 65 and 70 mm (2.56 and 2.75 in.) and the thickness of the web 14 mm (0.55 in.).

The modulus of resistance is more than 200 cm³ and the moment of inertia lies between 1800 and 2 100 cm⁴.

The Austrian Railways also use joints laid on metal sleepers (Fig. 9).

The most common practice is the join carried on assembled sleepers, 250 — 260 mm (9.84 — 10.23 in.) between centres.

A similar arrangement is adopted in the case of metal sleepers. The Secondary

Swedish Railways use joints laid on three sleepers 425 mm (16.73 in.) apart. The Portuguese Railways use over-hanging joints on wood sleepers, 490 mm (19.29 in.) apart.

The tracks on this line were so laid in 1936.

At the present time the Italian State Railways in order to increase the life in service of old rails have welded them on

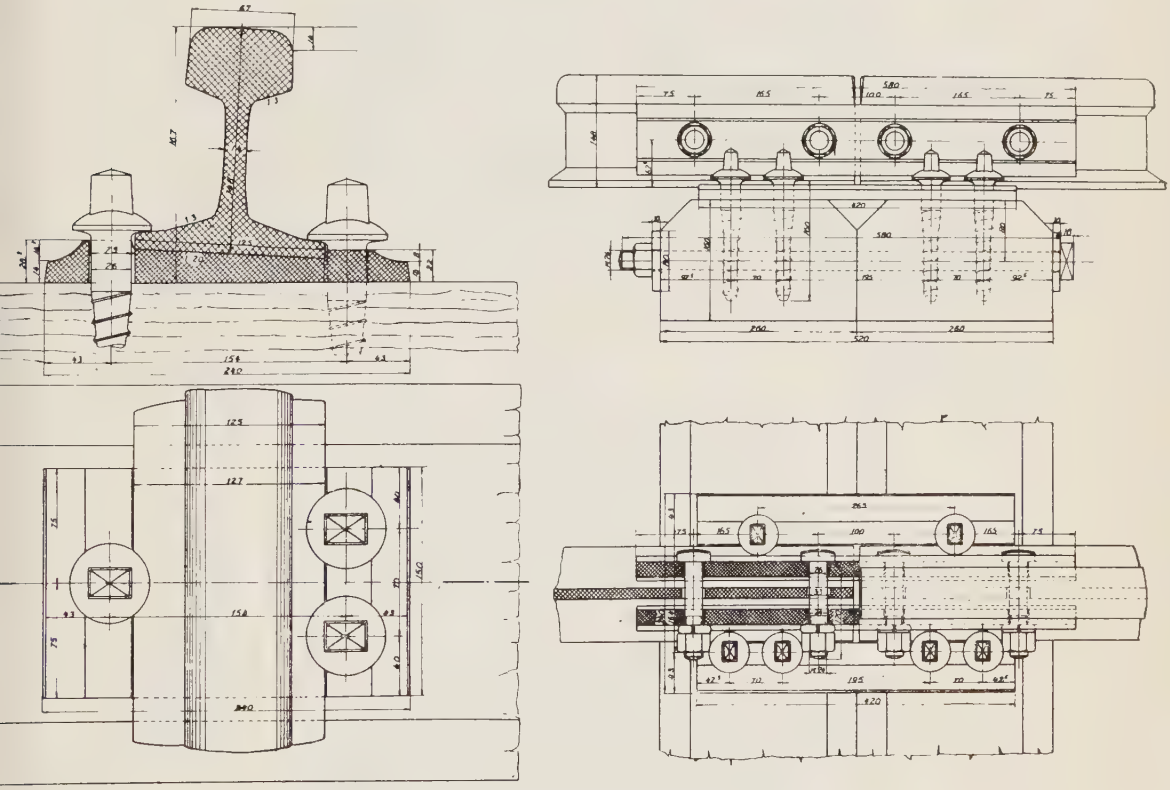


Fig. 2. — *Austrian Federal Railways.*
FORM B (S. 49) type of rail. — Joint carried on wood sleepers with direct fastenings.

3. *Are the rail joints opposite to one another or staggered (alterning) in position?*

3. The joints are in line side by side on all the railways. The Italian State Railways have recently made a trial of staggered joints on a double track main line 219 km long. Results (comfort, stability, etc) at the highest speeds (160km [100 miles]/h in the case of electrotrains and 120 km [74 miles]/h in the case of ordinary trains) have been very satisfactory, even in relation to defects in alignment

site into lengths of 36 m (118′ 1 1/4″) with staggered joints. It has been remarked that in spite of the wear of the fishplate surfaces and deformation of the ends of the rails, this system has in fact improved the running of the trains appreciably.

4. *Give the maximum and minimum width of the joint and counter-joint sleepers, i. e. the sleepers carrying the joint and those immediately adjoining.*

4. The Italian State Railways use wood

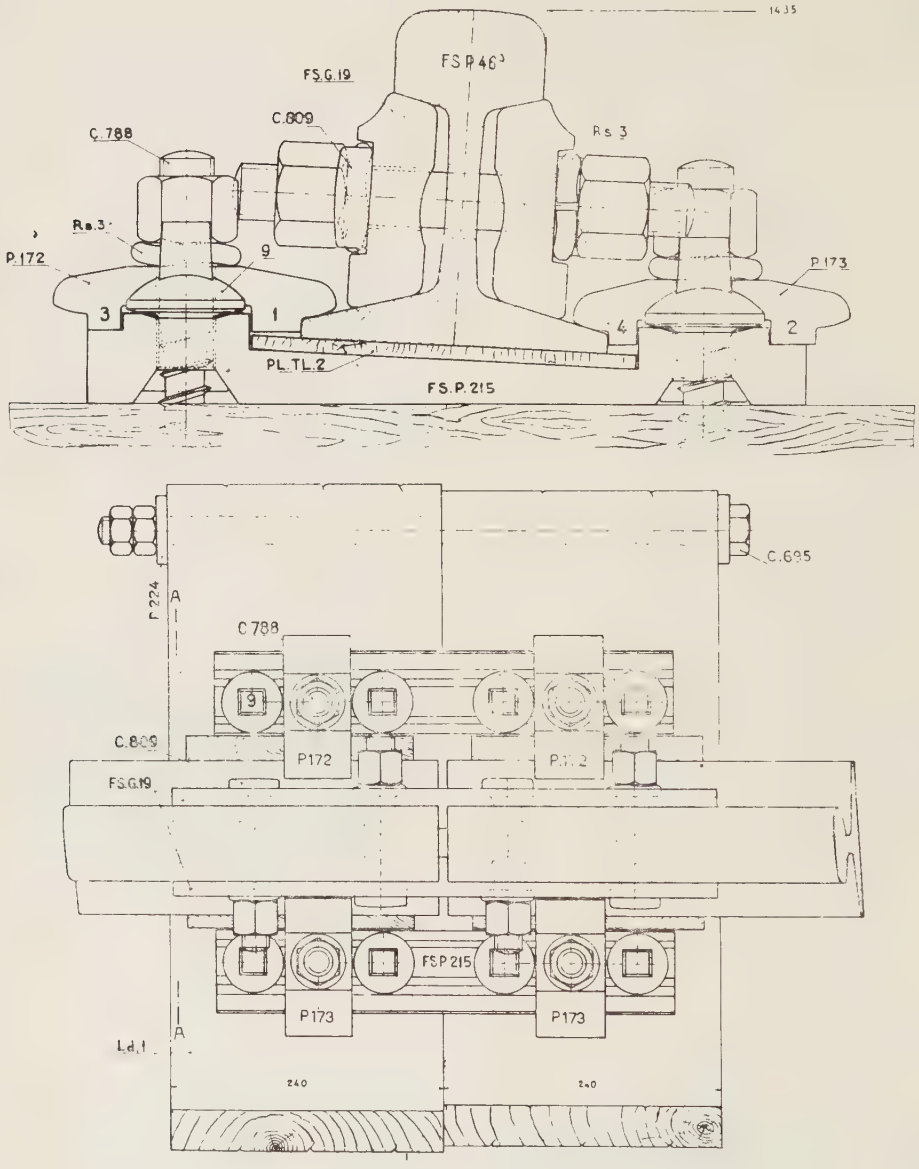


Fig. 3. — *Italian State Railways.*
FS. P. 46³ and 50⁶ type of rail. — Joint carried on wood sleepers with indirect fastenings.

sleepers, 240 × 140 × 2 600 mm (9.45 × 5.51 × 102.3 in.), occasionally 260 × 160 × 2 600 mm (10.23 × 6.30 × 102.3 in.), whereas the Austrian and Swedish Railways use wood sleepers of the following sizes : 260 × 160 × 2 600 mm and 260 × 160 × 2 700 (10.23 × 6.30 × 106.3 in.) for the joint sleepers and adjoining sleepers.

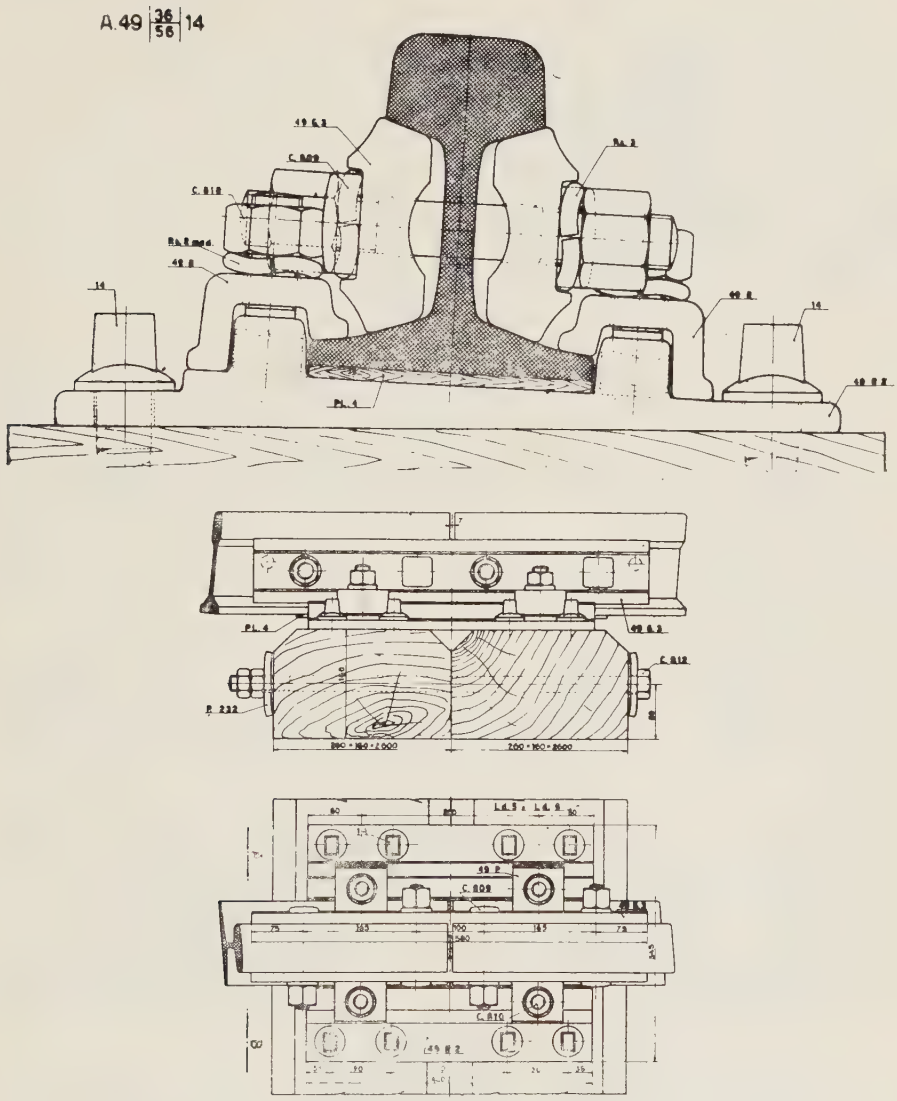


Fig. 4. — *Italian State Railways.*

TIPO 49 type of rail. — Joint carried on wood sleepers with indirect fastenings.

It was not stated however whether these larger dimensions were chosen owing to the kind of wood used for the sleepers (deal, fir, etc.) or because of the need to increase the resistance of the track to moving on the ballast or for other reasons.

The Austrian Railways also use metal sleepers with a bearing surface of 130 mm (5.11 in.).

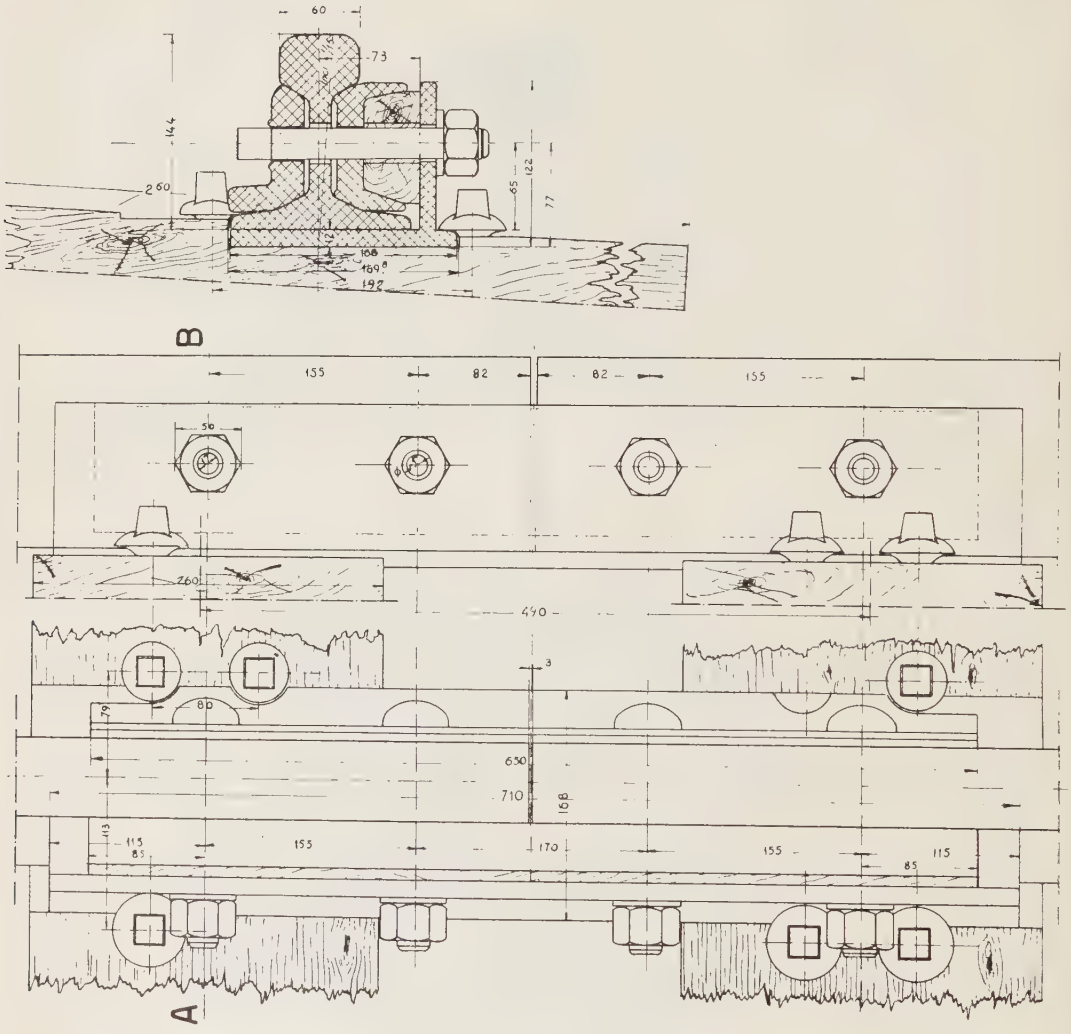


Fig. 5. — *Portuguese Railways.*
Type 45 type of rail. — Over-hanging packed joint on wood sleepers.

5. *Describe the joint and supply dimensioned drawings.*

5. In Tables I and II are given the characteristic dimensions of the joints used by the different railways (Fig. 1, 2, 3, 4, 5, 6, 7 and 8).

6. *Describe the cross sectional form of the fishplates used and explain the reasons for your choice :*

— *flat,*
— *angle,*
— *with ribs,*
— *bridge (part engaging under the foot of the rail),*
— *various.*

Give the characteristics of each type : i. e. the surface of the section, the moment of inertia and the modulus of resistance. What proportions in relation to the same rail characteristics?

6. The Italian and Austrian Railways use flat reinforced fishplates, as do the Swedish State Railways.

The Portuguese Railways on the other hand use a type of joint with a packing. The Swedish Secondary Railways use fishplates with reinforced angles.

The characteristics of the fishplates (surface of the section, moment of inertia and modulus of resistance) and their proportions compared with the same characteristics for the rails are given in Table III.

The cross sectional form of the fishplates used is a function of the arrangement of the sleepers near the joints.

7. *Describe the longitudinal form of the fishplates and its features: does it bear on the rail over its whole length, on the one hand on the foot or lower flange and on the other on the head?*

7. All the railways use fishplates which bear over the whole length of the fishplating, both foot and head.

In the bushed joints of the Portuguese Railways contact is assured by flat fishplates.

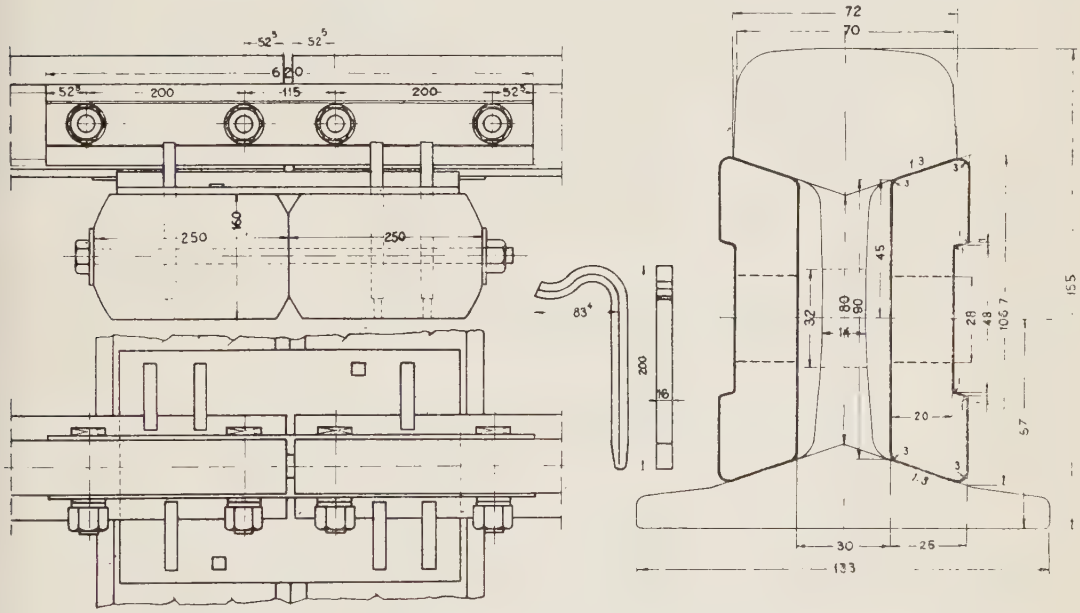


Fig. 6. — *Swedish State Railways.*
1940 Mod. ARS type of rail. — Joint carried on wood sleepers; direct fastenings with elastic clips.

8. *What is the slope of the fishplate bearing on the head and on the foot or lower flange?*

Does the fishplate bear over the whole width of the fishplate bearing?

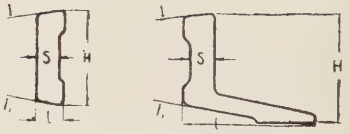
Is this surface of the fishplate machined (rectified by machine) or not?

Justify the arrangements adopted in each of these three cases?

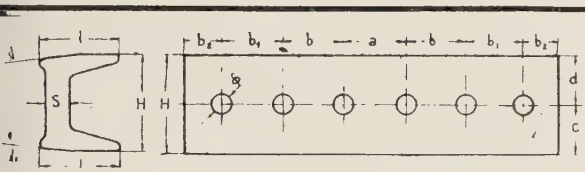
8. From the replies received to our questionnaire, it appears that apart from the Portuguese Railways which have adopted

TABLE

Types of

Administration	Type of fishplates						
		Length mm	Maximum height mm	Width: Minimum mm	Width: of the angle mm	Cant of the fishplate bearings	
Railways :		L	H	S	l	I	I_1
AUSTRIA : *Federal*	Fl. 16. Flat reinforced	580	93.7	20	—	1 : 3	1 : 3
ITALY : *State*	FS. G. 19. Flat reinforced for types of rails FS. P 46.3 and 50.6	475	94	22	—	1 : 4	1 : 4
	49 G. 3. Flat reinforced for type TIPO 49	580	93.5	22	—	1 : 3	1 : 3
PORTUGAL :	Inner angle fishplate	650	94.858	24	55	1 : 2	1 : 2
	Outer double angle fishplate	650	98	18	53 53	1 : 2	1 : 2
SWEDEN : *State*	Type AV 1940 ARS. Flat reinforced fishplate	620	105	20	—	1 : 3	1 : 3
	Type AV. 1924 ARS. Angle fishplate	560	94.4	19	70.5	1 : 2.75	1 : 3.75
SWEDEN : *Private*	43.2 kg/m. type of rail Reinforced angle fishplate	915	102	19	99	1 : 2.75	1 : 3.75

plates.



∅	Number of holes	*a*	*b*	b_1	b_2	*d*	*c*	Weight	Section	Modulus of resistance W	Moment of inertia J
mm		mm	mm	mm	mm	mm	mm	kg	cm^2	cm^3	cm^4
26	4	100	165	—	75	46.75	46.75	9.200	20.93	31.6	147.2
26	4	105	110	—	75	45.5	48.5	8.510	23.95	35.9	169.2
26	4	100	165	—	75	46.75	46.75	10.763	24.56	36.1	168.8
27	4	170	155	—	85	43.313	51.545	12.500	26.30	34.63	191.4
27	4	170	155	—	85	45	53	11.500	23.28	47.16	231.1
28	4	115	200	—	52.5	52.5	52.5	10.200	22.58	36	190
26×26	4	115	150	—	72.5	48.4	46	10.000	25.09	24.9	195.12
26×26	6	115	150	150	110	48	54	18.900	27.62	42	255.20

TABLE III.

Percentages between rail elements and corresponding fishplate elements.

Administration	Type of fishplate	Section cm^2			Moment of inertia I cm^4			Modulus of resistance W cm^3		
		Rail	Fishplate	%	Rail	Fishplate	%	Rail	Fishplate	%
Railways :										
AUSTRIA : *Federal*	FORM-B (S 49)	62.48	20.93	33	1797	147.2	8.1	239	31.6	13.2
ITALY : *State*	FS. P. 46.3	59.26	23.95	40	1663.7	169.2	10.1	217.3	35.9	16.5
	FS. P. 50.6	64.79	23.95	36	1894.5	169.2	9	236.4	35.9	15.1
	TIPO 49	62.48	24.56	39	1797	168.8	9.3	239	36.1	15.1
PORTUGAL : *Portuguese Cy*	45	57.85	26.30	45	1571	191.4	12.1	203	34.63	17
			23.28	40		231.1	14.7		47.16	23.2
SWEDEN : *State*	Rail 1940 Mod. ARS	63.7	22.58	35	2046	190	9.2	258	36	14
	Rail AV 1924 ARS	55	25.09	46	1310	195.12	14.8	189	34.9	18.4
SWEDEN : *Private*	43.2	55	27.62	50	1310	255.20	19.4	189	42	22.2

an inclination of 1/2 for the fishplate bearing surface, the other Railways use an inclination of 1/3 both on the head and on the foot.

The Italian State Railways have inclinations of 1/4 with their old 46.3 and 50.6 kg/m rails.

The joints on the A V 1924 A R S Modell track used by the Swedish State and Secondary Railways have an inclination of 1/2.75 on the head side and 1/3.62 on the foot side.

No Administrations machine the fishplate bearing faces.

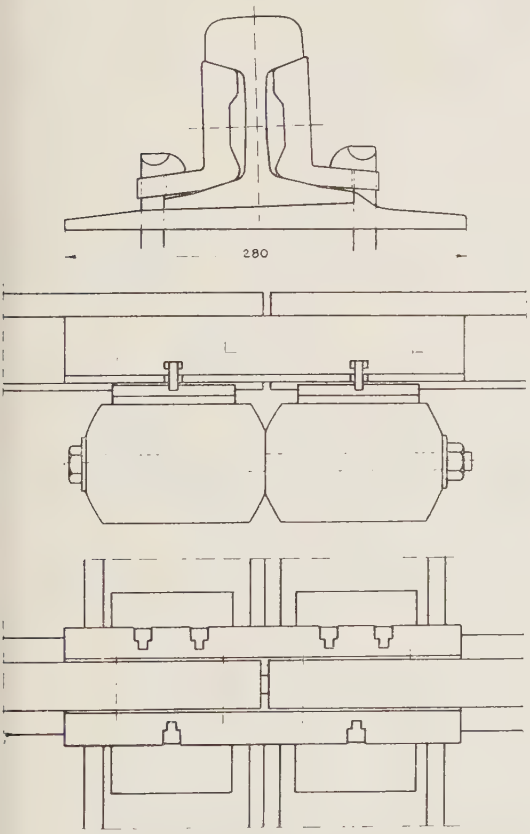


Fig. 7. — *Swedish State Railways.*
AV. 1924, ARS type of rail. — Joint carried on wood sleepers; direct fastenings with ordinary clips.

The Railways also report that the fishplate bears over the whole of the length of the fishplating; the contact surface of the fishplates is shown in Table IV.

The inclination of 1/3 of the fishplate bearing surfaces and the arrangement adopted by the Railways appear to be the best for the wedging action.

The Italian State Railways have chosen a symmetrical section of fishplate for their type 49 track, so that they can turn over the surfaces showing appreciably wear due to rubbing at the points of the rail.

The results obtained are considered very satisfactory by the Railways.

9. *Is the rail drilled or not? If it is, give the arrangement of the fishplate holes, number, spacing? Does the position of the holes depend on the fastenings of the rails to the sleepers?*

9. Table I gives details concerning the arrangement of the holes in the rails.

All the Railways have rails drilled at both ends. Apart from the Swedish Secondary Railways, who have not adopted an arrangement of the holes in the rails and fishplates in relation with the fastenings of the rail to the sleepers, the other Railways have investigated the siting of the holes in such a way that the fastenings come in between the two fishplate holes, in order to facilitate tightening up the nuts on the bolts and clips, as well as tightening the coachscrews.

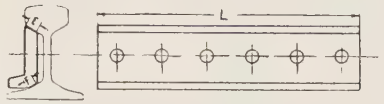
10. *What tolerances are allowed as regards differences in wear of running surface of two rails in contact?*

If these differences exceed the tolerances, what arrangements are used? (packing pieces, special fishplates, etc.).

10. The replies received show that the Railways all use identical systems for maintaining the running surfaces of the rails in contact level with each other, should unequal wear lead to different heights; if the differences are not important, they use packings, and in the case of greater wear, special fishplates with flat surfaces.

TABLE IV.

Dimensions and bearing of the fishplating.

Administration	Type of rails	Fishplate bearings					
							
		Dimensions			Area		
					Part		Total
		E mm	F mm	L mm	L×E cm²	L×F cm²	cm²
Railways :							
AUSTRIA : *Federal*	FORM-B (S 49)	17	17	580	99	99	198
ITALY : *State*	FS. P. 46.3	17	25	475	81	119	200
	FS. P. 50.6	17	25	475	81	119	200
	TIPO 49	17	20	580	99	116	215
PORTUGAL : *Portuguese Cy*	45 interior	16	16	650	104	104	208
	45 exterior	15	16	650	98	104	202
SWEDEN : *State*	Rail 1940 Mod. ARS	20	20	620	124	124	248
	Rail AV 1924 ARS	20	25	560	112	140	252
SWEDEN : *Private*	43.2	20	23	915	183	210	393

The Swedish Railways in the case of small differences (of some mm) grind the running surface of the two rails in contact. For good running of the rolling stock, the difference in height should not exceed 1.5 mm (0.057 in.).

owing to the running of the trains, are subjected to great fatigue and rapid wear, especially on lines with heavy traffic, the above idea may have advantages which must naturally be compared with the economic aspect of the question.

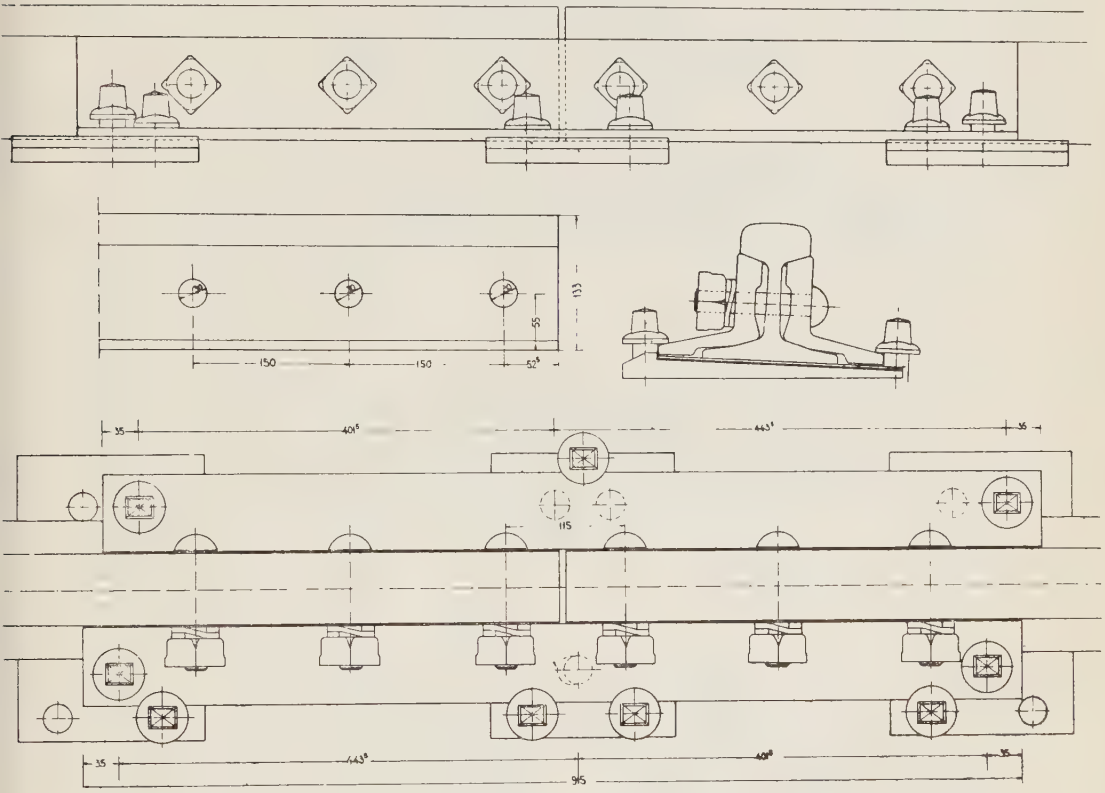


Fig. 8. — *Swedish Private Railways Union.*
43.2 kg (93 lbs) type of rail. — Joint carried on three wood sleepers, one under the centre, with the rails secured by fishplates.

11. *Have you made use of joints made up from two new rails cut from the same rail in order to obtain absolutely identical ends of the rails?*

11. No Administration reported the use of joints made up from two new rails cut from the same rail to obtain absolutely identical rail ends.

In view of the fact that joints on new rails,

12. *Do you endeavour to prevent or do away with burrs at the ends of rails in the joints? What methods do you employ?*

12. To prevent the formation of burrs at the ends of rails, it is necessary, apart from more careful maintenance of the track, to heat treat the ends of the rails and to regulate the joint gaps perfectly.

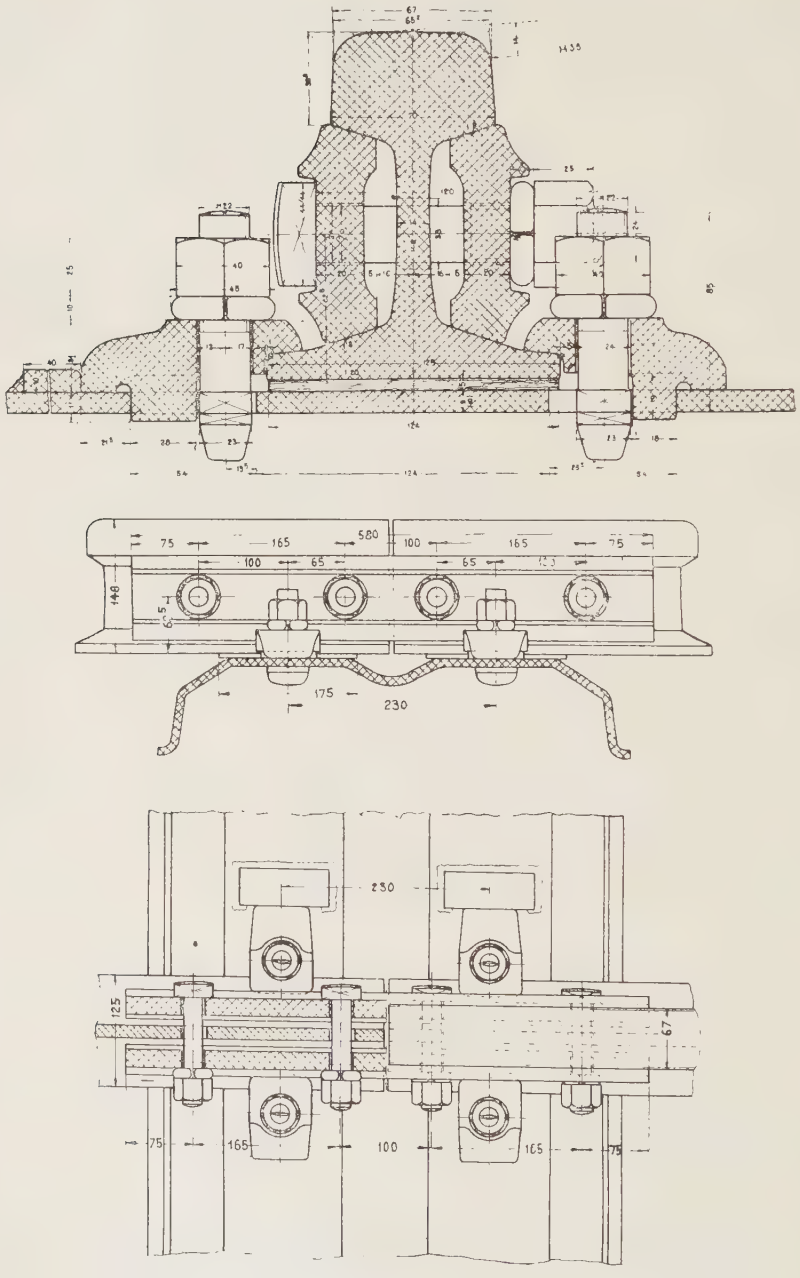


Fig. 9. — *Austrian Federal Railways.*
FORM B. (S. 49) type of rail. — Joint carried on a double metal sleeper.

No other details were supplied by the Railways.

The Austrian, Italian State and Swedish Railways are already receiving rails from the mills with the ends chamfered off.

Burrs are done away with on site, during maintenance operations, with a file or chisel.

13. *Do you make use of spectal devices wtth the fishplating to support the rails? Single or double bearing plates? Special supports? Flat sole plates, etc...*

13. The figures show the various types of joints used by the Railways.

Apart from the Swedish Railways the other Railways use double bearing plates to support the joints with wooden packings inserted between the double plates and the rails.

The Austrian and Italian State Railways use double bearing plates with a hole in the middle 120 × 127 mm (4.72 × 5 in.) to make the joint more elastic when rolling stock runs over it.

The Portuguese Railways use a joint with a cover piece with a wooden wedge, and the Swedish State Railways, double bearing plates.

The Italian State Railways also use double bearing plates, without any hole in the middle, with their old rails.

The Swedish Secondary Railways, in the case of joints carried on three sleepers, join each fishplate to the bearing plate and the sleeper by coachcrews, two of which are driven through the angle of the fishplate.

The Italian State Railways and the Austrian Railways have adopted a flat fishplate for use on their 49 kg (108 lbs) type track with no provision for joining it to the sole plate in view of the fact that indirect fastenings prevent rail creep very effectively.

14. *Give the arrangements adopted to enable the rails to expand. Diameter of the bolts. Diameter of the holes in the rails and in the fishplates. Distance between the holes and in the case of the rails, from the ends of the rails.*

14. Table I gives the different distances between the holes at the ends of the rails and the fishplates, as well as the number and diameter of the holes.

The Italian State Railways and Austrian Railways use bolts having a diameter of 24 mm (15/16″) for their joints; the Portuguese Railways 25 mm (63/64″) bolts; the Swedish State Railways 25.4 mm (1″) and the Swedish Secondary Railways 22 mm (7/8″).

In comparison with these dimensions, the relative distances between the diameters of the holes in the rails and fishplates and the diameters of the bolts allow of a maximum joint gap of :

Italy	14 mm (35/64″)
Austria	19 mm (3/ 4″)
Portugal	12 mm (15/32″)
Sweden (State) ...	20 mm (25/32″)
Sweden (Secondary)	18 mm (45/64″)

15. *Give the amount of expansion allowed for when laying the track in terms of the temperature (see Part C of the questionnaire).*

15. The free expansion allowed when laying the track is shown in Table VII (See the third part of the questionnaire.)

16. *Do you use wooden packings? How are they arranged?*
Do you make use of elastic fishplates? Arrangement and drawings. Remarks.

16. With the exception of the Portuguese Railways, the other Railways make use of compressed ,impregnated wooden sole plates, inserted between the foot of the rail and the single or double bearing plates.

The material used is white poplar wood, poplar, masonite, and not elastic material.

To keep the wooden sole plates in good repair and working properly, there must be no play between the foot of the rail and the ribs of the sole plates; the sole plates must be of the same width as the foot of the rail.

Wooden sole plates on double track lines have the drawback of sliding in the same direction as the trains travel.

The Italian State Railways have found that the running on lines equipped with wooden sole plates is softer and more uniform.

Only the Portuguese Railways make use of joints with wooden packings (See Fig. 5). No further information was supplied on the subject.

17. *Give the characteristics of the bolts: diameter, length, thread, shape of the head, shape and size of the nut. Reasons.*

17. Table V shows the different types of fishplates and fixing bolts.

Apart from the Portuguese Railways who use fishplate bolts with a semi-cylindrical head, on a rectangular base, the other Railways use square headed bolts; this shape fits very snugly into the slot on the outer side of the fishplate, preventing the bolt turning when the nut is tightened up.

18. *Do you use any device to prevent the bolts working loose, for example: check-nuts, spring washers, springs, etc.? What results have you obtained?*

18. Only the Portuguese Raillways use cylindrical washers with a plane surface; the other Railways use spring washers.

The Austrian Railways use spring washers with single and double spirals; the Italian State Railways use single spiral corrugated spring washers, and the Swedisch State and Secondary Railways double spiral spring washers.

The single spiral corrugated spring washers used by the Italian State Railways on joints have a rectangular transversal section with one side of the outer section semi-circular.

The spring washers used by the Austrian Railways are of two kinds : single spiral washers of rectangular section similar to the type used by the Italian State Railways but without corrugations; and those with double spirals of rectangular section, thinner than the single spiral ones.

The Swedish State Railways, and Secondary Railways use double spiral spring washers of rectangular section.

In general the behaviour of these various types of washers is considered satisfactory.

19. *Are the nuts on the inside or outside of the track? Why?*

19. In Portugal and Austria, the Railways use bolts with the nuts on the inside of the track to facilitate inspection; other Railways put half the nuts on the inside and half on the outside (Italy), or all the nuts on the inside (Sweden) to save them from breaking or damage in case of accidents.

20. *How are the fishplates manufactured? Do you make use of special steel or heat treatment?*

20. The fishplates used by the Railways are manufactured in steel by rolling; subsequent work is done cold; they are cut, drilled and given the desired dimensions, without any machining of the surfaces of the fishplating.

Only the Italian State Railways up to the present have gone in for normalising the steel used for fishplates by heat treatment.

Experience has proved that normalising is effective in preventing breakages at the holes and slots.

21. *Give the inspection conditions and tests for fishplates, fishplating devices and the whole of the joint?*

21. On the Italian State Railways the fishplates undergo the main tensile and bend tests.

Tensile tests are carried out with test pieces of circular section taken from the finished fishplates after normalising, machined cold.

The test pieces should break under a traction force of between 50 and 55 kg/mm^2 (31.75 and 34.92 tons per sq. inch.) and have such a percentage of elongation that the product of this value multiplied by the breaking load, determined in kg/mm^2 (coefficient of quality) is not less than 1 100.

Administration	Type of rails	Bolt: Shape of the head and size	Bolt: Diameter bolt ø	Bolt: Diameter threaded part ø	Bolt: Thread	Bolt: Length total L	Bolt: Length threaded part l	Nut: Shape	Nut: Width S
Railways :									
AUSTRIA : *Federal*	FORM-B	1) Square fishplate bolt 44 × 44 × 16	24	24	3	130	60	hexagonal with bottom washer	39
		2) Semi-circular fastening bolt, 30 × 53.5 × 17, with a rectangular base	22	22	2.5	65	50	blunted hexagonal	39
ITALY : *State*	FS. P. 46.3 FS. P. 50.6	1) Square fishplate bolt 44 × 44 × 16	24	24MA	3 (Uni 159)	140	70	hexagonal	38
		3) Fastening bolt of trapezoidal section $\frac{40 - 27,9}{45}$	24	24MA	»	95	50	»	38
	TIPO 49	1) Square fishplate bolt 44 × 44 × 16	24	24MA	»	140	70	»	38
		2) Semi-circular fastening bolt 30 × 53.5 × 17, with a rectangular base	22	22MA	»	60	50	»	38
PORTUGAL : *Portuguese Cy*	45	5) Semi-circular fastening bolt 50 × 25 × 25, with a rectangular base	25.4	25.4	3.175	160	50	hexagonal	40
SWEDEN : *State*	Rail 1940 ARS	1) Square fishplate bolt 44 × 44 × 16.	25.4	25.4	3.175 (Whitworth)	118	50	»	42
	Rail 1924 ARS	4) Mushroom headed ø 41×16	22.2	22.2	2.82	115	50	square with a round base ø = 40	41
SWEDEN : *Private*	43.2	1) Square fishplate bolt 41 × 41 × 28.	22	22	2.82	115	50	»	41

The bending tests are carried out as follows : the fishplates being tested, completely finished and heat treated, must bend in any direction when cold so that the bent part takes up an angle of 90° with a radius of curvature on the inside of 15 mm (0.59 in.) without any fissures or cracks occurring.

All the tests must be carried out at a temperature of between 22° and 35° C (71° and 95° F).

The Italian State Railways do not carry out any tests of assembled joints.

In Austria, the fishplates are cut cold from rolled bars and then drilled; they do not undergo any heat treatment.

To check their quality, tensile tests are made to fracture.

The profile of the rail is checked by means of gauges.

The Portuguese Railways make their fishplates from rolled steel bars with a breaking strength of 45 kg/mm² (28.57 tons per sq. inch.).

The Swedish State and Secondary Railways follow the specifications of the German Railways, namely : the fishplates are manufactured from rolled steel bars with a breaking strength of not less than 45 kg/mm².

The finished fishplates undergo bending tests cold.

No information was supplied by the Railways about tests of assembled joints.

22. *Give information about the maintenance of the fishplating :*

a) *Periodicity of taking down and if needs be greasing the fishplates;*

b) *Devices to make good wear of the fishplates surfaces (packing pieces for example;*

c) *Repairs to fishplates to enable their re-use.*

22. *a*) The Italian State Railways, Austrian and Swedish Railways, periodically (every 3 to 5 years) take down the fishplates to check them and grease them.

b) To make good wear of the fishplate bearing surfaces, the Railways make use of packings.

The Austrian Railways also reforge worn fishplates;

c) Cracked fishplates are repaired by welding. Only the Austrian, and Swedish State Railways re-use fishplates that have worn down in height after hot stamping.

The other railways do not repair their fishplates; they are scrapped.

However, in general, it has been found that when the fishplates are very worn on the bearing surfaces, they have also deteriorated near the holes; consequentlv there is no point point in repairing them.

23. *Maintenance of the joint itself. Do you take any steps to assure the correct level of joints being restored? At what intervals?*

23. The Railways during periodical maintenance operations according to the interval applying to the line in question, take up the joints by a thorough tamping of the sleepers carrying these joints, without touching the others, so as to raise the ends of the rails.

At this time any worn or broken fisplates are also replaced and the fishplate bearing surfaces greased.

The Swedish State Railways in order to facilitate raising the joints make use of fishplates which are slightly arched on top (0.5 mm = 0.0197 in.).

In addition to this periodical maintenance which is based on the amount of traffic, the nature and quality of the ballast, as well a the state of repair of the track, the Italian State Railways carry out a systematic check up of the joints once or twice a year.

24. *Have you experienced any differences in maintaining the level of the track near joints due to differences in the types of fishplates and the arrangement of the joints (staggered or in line)?*

24. It appears that the Railways have found joints carried on assembled sleepers with double sole plates better than overhanging joints.

The Italian State Railways have found that the elasticity obtained by staggering the joints is greater than with joints in line with each other, in spite of the inevitable occurrence of a slight warping in the level of the track.

In general, difficulties experienced in maintaining the level of the track in line with the joint are due to the age of the material, the condition of the ballast, the bed and the atmospheric conditions (wet or dry).

If the material is more than 20 years old and it has not been decided to re-use the rails by cutting off the worn ends, it is better to stagger the joints.

overhanging joints fitted with slots for the fastenings, owing to the abnormal stresses to which they are subjected.

It can thus be stated that breakages in the fishplates are due above all to the age of the material, the condition of the joints, and the period of maintenance of the track.

The percentage of breakages of fishplates observed by the Italian State Railways is about 0.5 %.

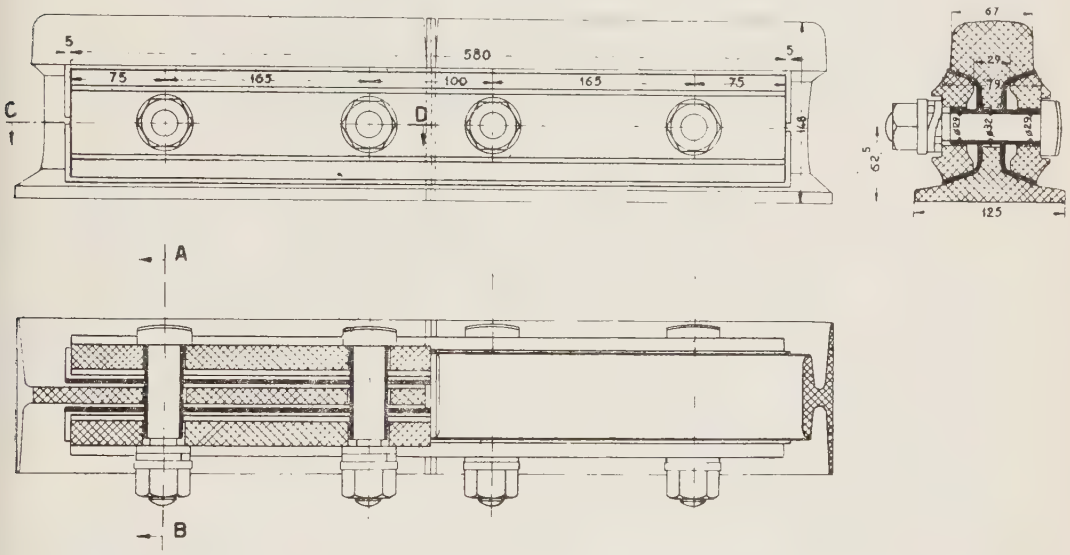


Fig. 10. — *Austrian Federal Railways.*
FORM B (S. 49) type of rail. — Insulated joint with metal fishplates and insulating fibre.

25. *Give a general idea of any facts noticed with different types of fishplates, percentage of breakages, difficulty of assuring the level, etc...*

25. In their replies, the Railways state that breakages of fishplates rarely occur; they are most frequent with fishplates at

26. *Give the main characteristics of insulated joints (dimensioned drawing).*

26. Generally speaking the Railways make use of smaller fishplates for insulated joints as regards the bearing surfaces, and insert some thicknesses of insulating material between them and the rails, up to 3 mm (1/8″) thick; fibre gaiters of the same profile as the rail, about 5 mm (13/64″) thick are inserted between the ends of the rails to be insulated; rings or sleeves, also made of insulating fibre are placed between the bolts of the joints and the fishplate holes or rail holes. (See Fig. 10 and 14).

The Austrian Railways have also made use of a type of insulated joint with a strong hardwood fishplate, with fibre between the ends of the rails; the rails rest on special double sole plates, overhanging, laid on two sleepers connected together by bolts, and spaced 35 mm (1 27/64″) apart.

laid on the main lines and obtained by direct rolling. Give the section of rail used (Vignoles, bull-headed) and weight per unit of length.

1. From the information received, it would appear that the standard Vignole

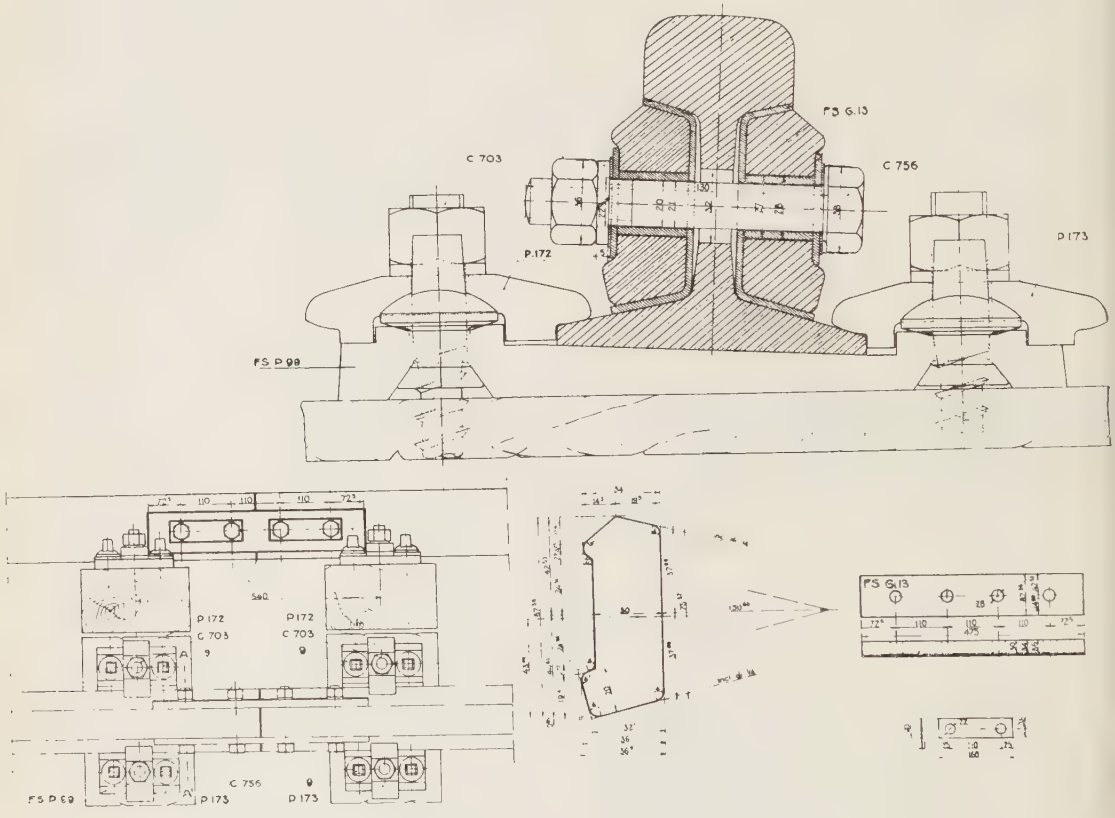


Fig. 11. — *Italian State Railways.*

FS. P. 46³ and 50⁶ type of rail. — Overhanging insulated joint with metal fishplates and insulating fibre.

Between the foot of the rails and the double sole bearing plates there are wooden packing plates. (Fig. 15.)

PART TWO.

Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way.

1. *Please give the standard lengths of rails* rails obtained by rolling are used by the Railways on the main lines, the weight per unit of length being as follows :

a) Austria : 30 m (98′ 5 1/8″) weight kg/m 49.05 (102 lbs.);

b) Italy (State Railways) : 36 m (114′ 10″) weight kg/m 49.05 (102 lbs.);

c) Portugal : 18 m 59′ 5/8″) weight kg/m 45 (99.2 lbs.);

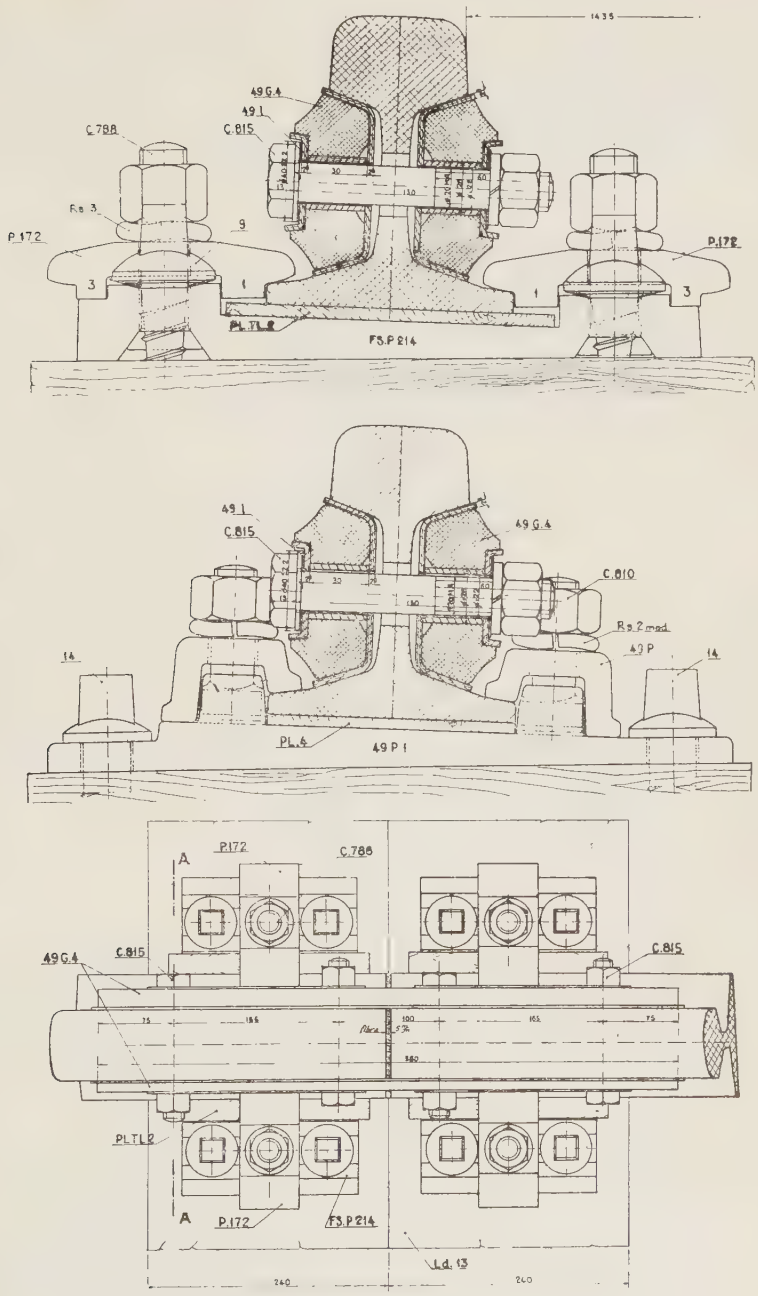


Fig 12. — *Italian State Railways.*

TIPO 49 type of rail. — Insulated joint with metal fishplates and insulating fibre. The sections show the arrangement with two different types of sole plates.

d) Sweden (State) : 20 m (65′ 7 3/8″) weight kg/m 50 (110 lbs.);

e) Sweden (Secondary Railways) 20 m (65′ 7 3/8″) weight kg/m 43.2 (95 lbs.).

The sections of the above rails are shown in Fig. 1 to 9.

a) Austria (welded in the shop by flash-butt welding) : 30 m, weight kg/m 49.05;

b) Italy (F. S.) : 36 m, weight kg/m 49.05; 48m (157′ 5 3/4″) weight kg/m 46.3 (102 lbs.);

c) Portugal : 36 m, weight kg/m 45;

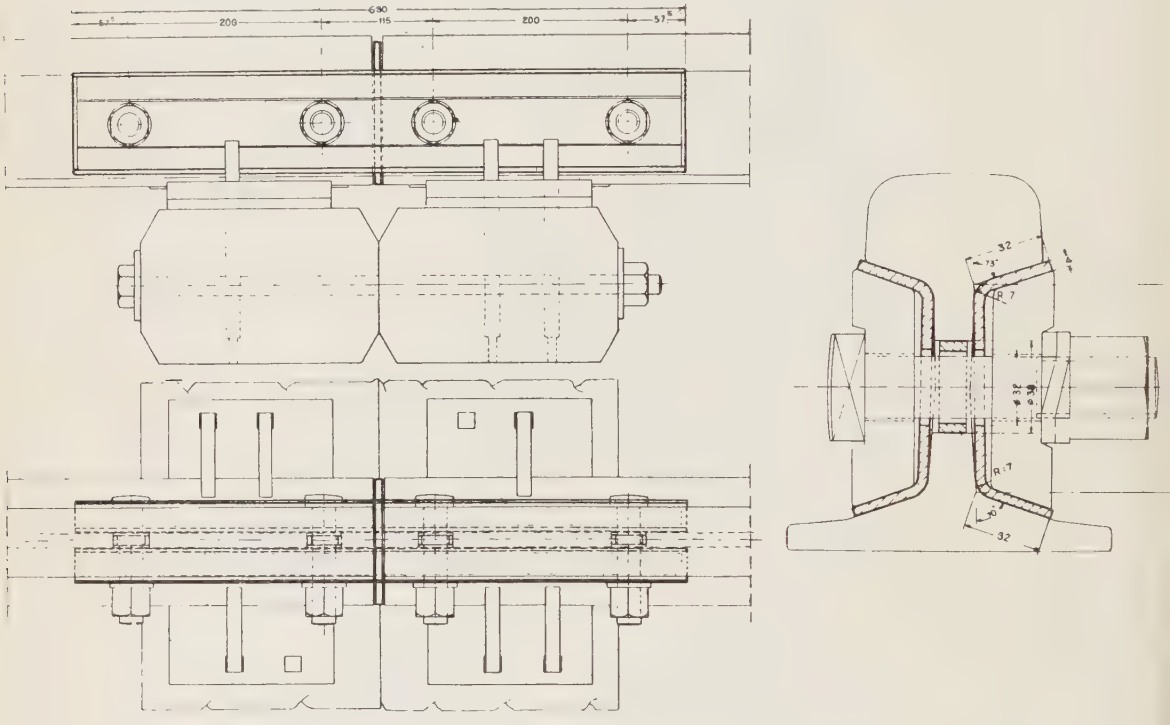


Fig. 13. — *Swedish State Railways.*
1940 Mod. ARS type of rail. — Insulated joint with metal fishplates and insulating fibre.

2. *What is the length of the long welded rails used as standard practice on the main lines run over by high speed trains and very heavy axle loads? Give the section of rail used (Vignoles, bull-headed) and the weight per unit of length.*

2. Long welded rails with the same sections and weights as given above are used as standard practice on the main lines run over by high speed trains with heavy axle loads, viz :

d) Sweden (State) : 30 m, weight kg/m 50 — 43.2 (110 — 95 lbs.);

e) Sweden (Secondary) : 40 m (131′ 2 3/4″) weight kg/m 43.2.

3. *Give the MAXIMUM lengths which you allow on your lines for welded rails of the types given above under question* 2. *Give details of the maximum length:*

a) *on the running line;*

b) on the main lines in stations and station sidings;

c) on metal bridges;

d) in tunnels.

In the last case, please give details of the lengths of rails used at the ends of the tunnel gradually to revert to the standard length of rails on the open line.

The general practice is to use longer lengths of rail in the open than those given under question 2) with special expansion devices.

In tunnels, on the other hand, it is possible to adopt the more advantageous solution of going away with joints completely, except at the ends, thus making a single rail through the tunnel, as the Italian State Railways have reported.

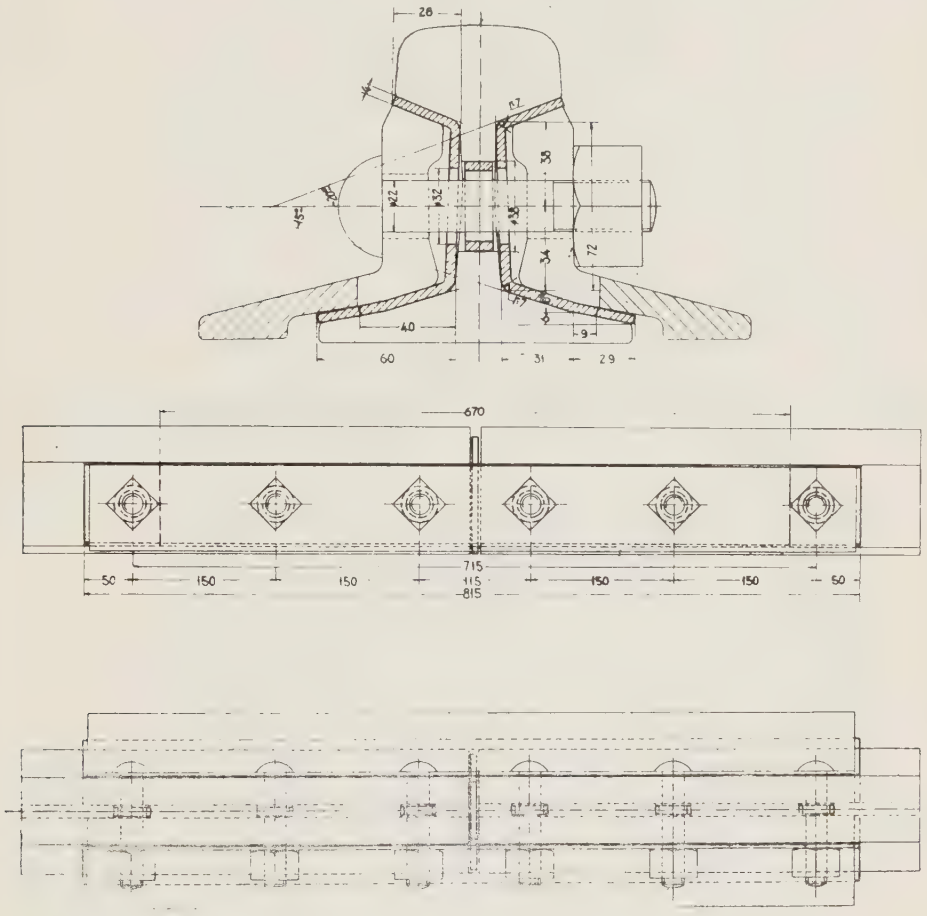


Fig. 14. — *Swedish Private Railways Union.*
43.2 kg type of rail. — Insulated joint with metal fishplates and insulating fibre.

3. The maximum lengths allowed for welded rails of the types given above under question 2 are shown in Table I.

Table VI gives the lengths of rails used

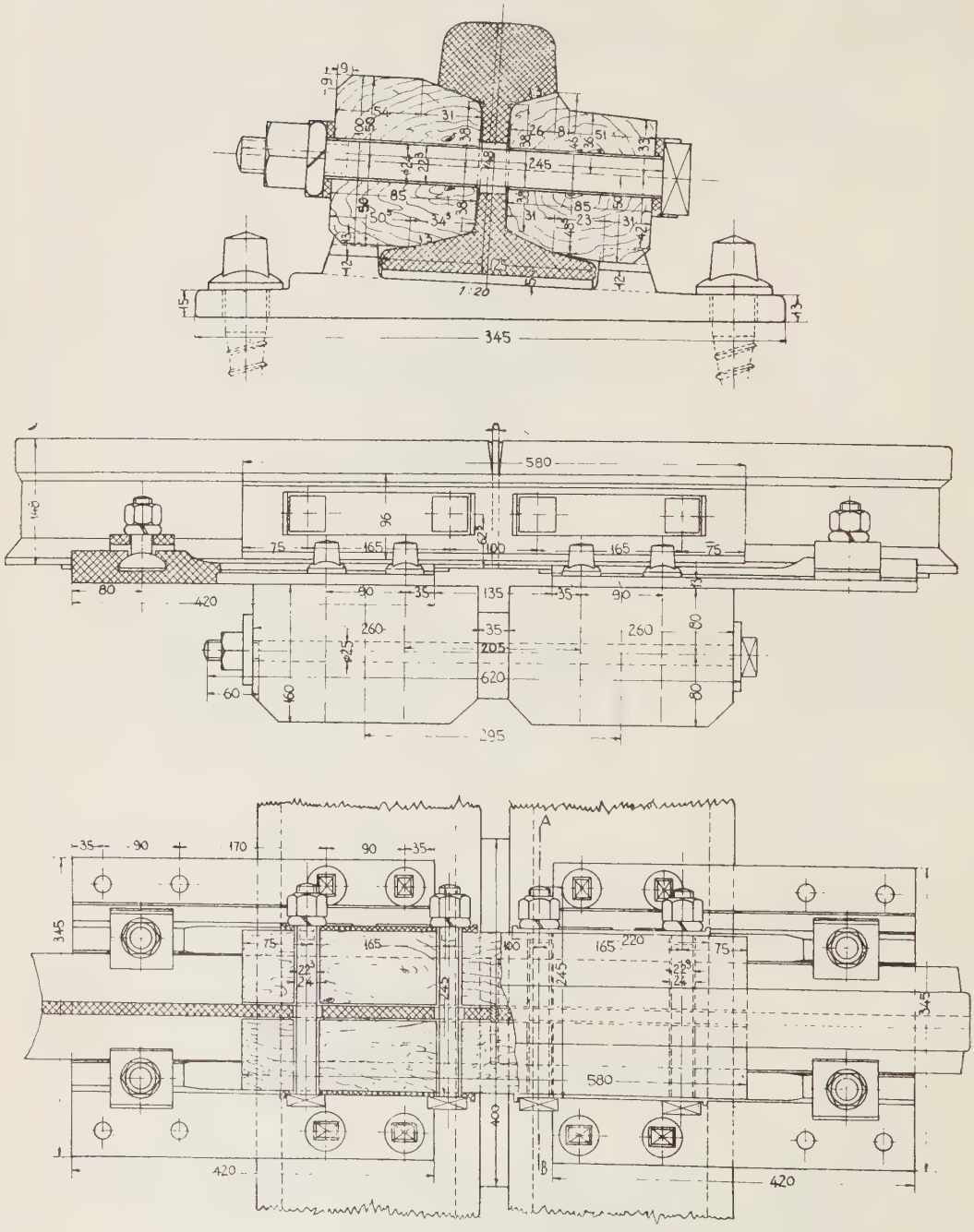


Fig. 15. — *Austrian Federal Railways.*
FORM B. (S. 49) type of rail. — Insulated joint with wooden fishplates.

to revert gradually to the standard length of rail in the open.

4. *Describe how the rails are fastened to the sleepers (with or without sole plate, chairs, etc...).*

4. Apart from the Portuguese Railways who lay their rails without sole plates directly on the sleepers (except for the joints which are laid on sole plates), Sweden makes use of direct fastenings with sole plates fastened by means of elastic clips or coachscrews.

These clips or coachscrews, in the case of joints with angle fishplates, press against the angle.

In Austria on the other hand ribbed sole plates are used with indirect fastenings or chaires with wedges.

The Italian State Railways use sole plates with indirect fastenings, but on the oldest types of track use sole plates with partly direct and partly indirect fastenings.

The Italian State Railways always use indirect fastenings with their longest rails (48 m).

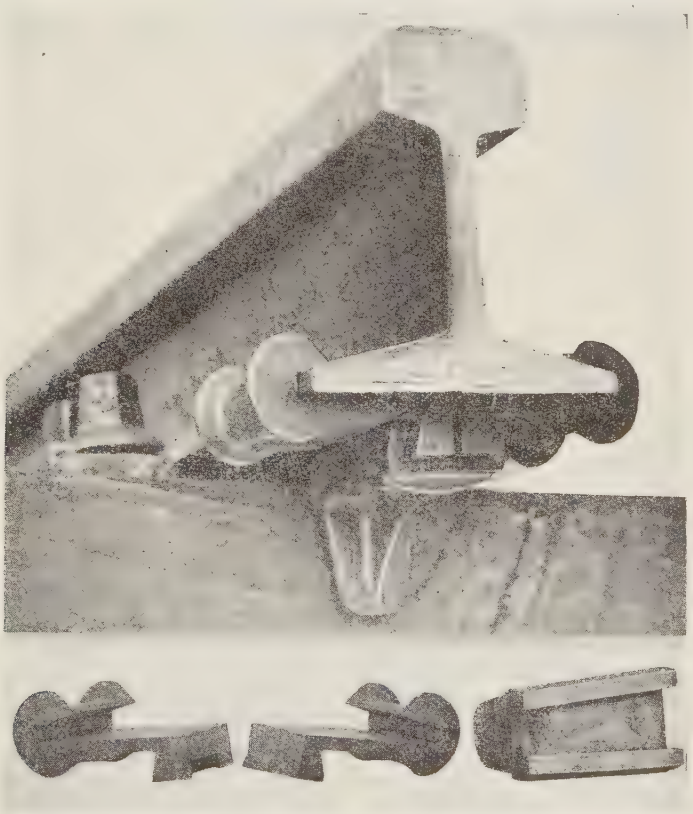


Fig. 16. — *Italian State Railways.*
Anti-creep devices, as fitted and taken apart.

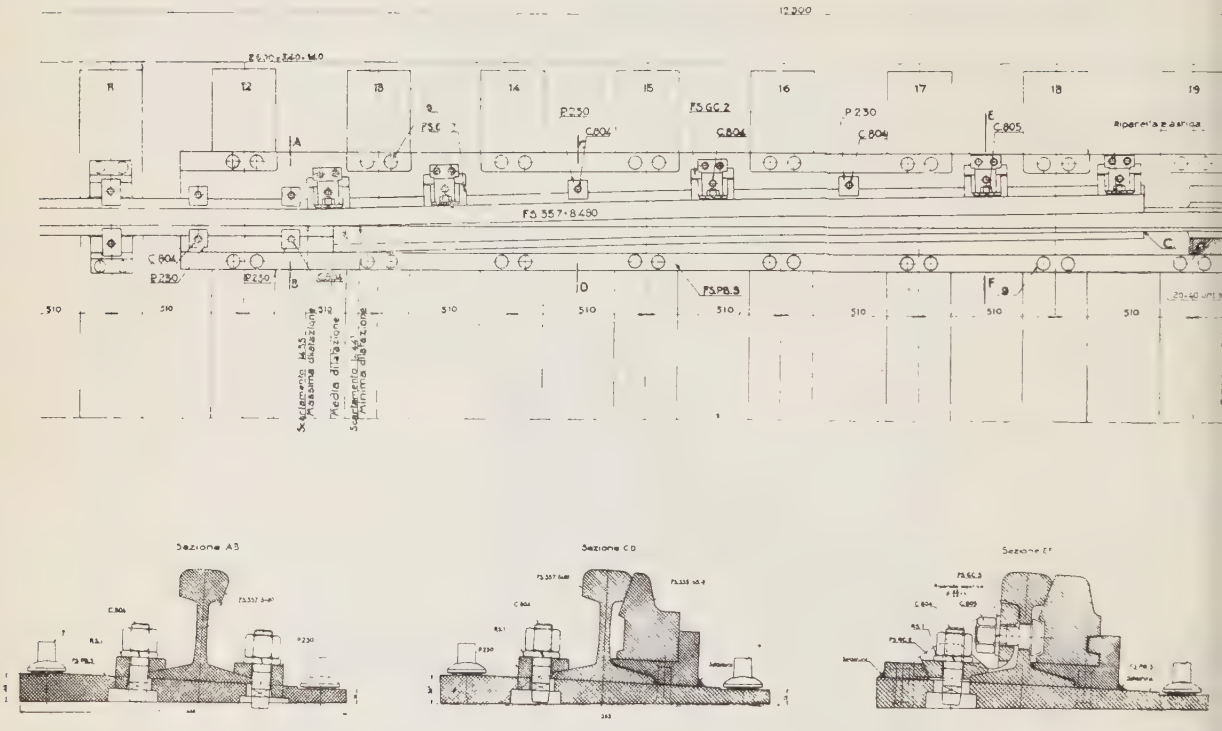


Fig. 17. —
Special ex

5. *Do you use anti-creep devices? Number and kind per rail.*

5. Anti-creep devices are used by the different Railways when the track is laid with direct fastenings and abnormal creep of the rails is noticed; for example near metal bridges fitted with special expansion devices, at level crossings, near points and other stopping points, on gradients, near signals where trains frequently stop.

Usually, the anti-creep devices are sited in the middle of the rail length; the idea is to make an invert linked up with the adjoining sleepers.

The most usual anti-creep devices are of the Wimby, Fair and similar types (Italy, Portugal), and the Paulus-Krupp type (Sweden).

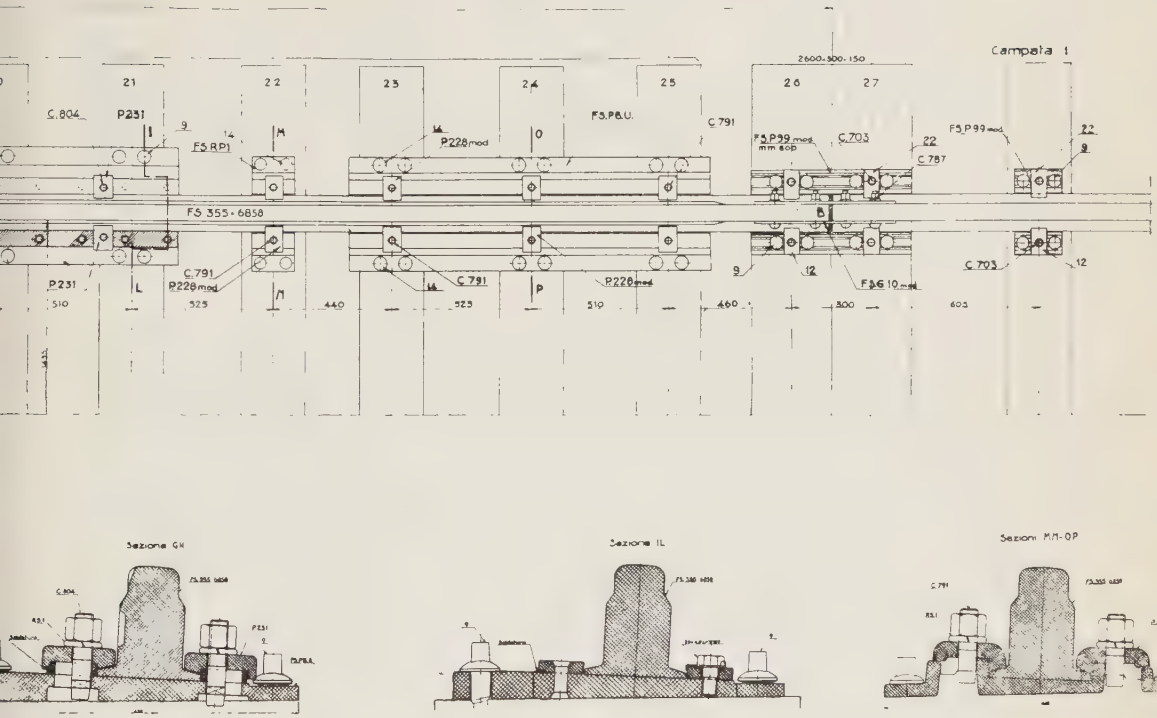
Fig. 16 shows the anti-creep devices of the Italian State Railways as fitted, and taken apart.

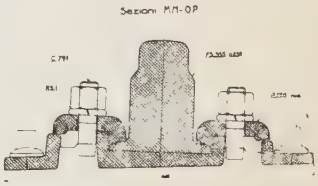
6. *How are the sleepers arranged in the open near welds and joints? Is there any ratio between the number of sleepers and the length of the rail?*

6. The Railways arrange the sleepers on the open line near welds (the welds are made on site, with the aluminothermic process) at approximately the same distances a part as sleepers at joints, with an overhang.

In the case of welds made in the shop with flash-butt welding equipment, the welded part can be placed in the centre of the normal spacing of the sleepers.

The arrangement of the sleepers with the usual joints is shown in Table I (See Part I).





Railways.
uipment.

The Italian State Railways have based their sleepering on the axle loads allowed on the line in question according to the operating conditions (electric or steam traction).

In Austria, there are 1567 sleepers per km on the open line, in Portugal 1667, while the Italian State Railways use 1 667 to 1 567 per km.

However, the Italian State Railways, when welding rails into long lengths on site, also retain the existing sleepering of 1444 to 1400 sleepers per km.

The Swedish State Railways use 1567 and 1544 sleepers per km, and the Secondary Swedish Railways 1400 per km.

Regarding the number of sleepers on lines equipped with very long rails, it has been noticed that the Railways who are not so much concerned with the length of the rails, have above all taken into account the unit stress due to the maximum axle loads allowed and the operating conditions on the lines in question.

Consequently, the tendency in this case is to increase the number of sleepers, so as to meet future operating requirements (increasing the axle loads of the vehicles, altering the method of traction, increasing the train speeds, etc...).

7. *State the kind of ballast used in each case.*

7. As regards the kind and quality of ballast used on lines equipped with very long rails, the Railways have reported that the ballast is made from broken stones.

Austria and Sweden also use gravel.

As regards the quality of the material,

TABLE VI.

Use of long rails.

Administration	Vignole type of rails — Weights per linear metre kg	Standard length on main lines in the open — obtained by rolling ml.	Standard length on main lines in the open — welded ml.	Maximum lengths of welded rails, type of welding and special joints at the ends. — on the running line ml.	on sidings ml.	on bridges ml.	in tunnels ml.	Fastenings	Remarks
Railways : AUSTRIA : *Federal*	49.05	30	30	30 flash-butt welding in the shops. 45 in the P.L.	60 in yards near the hump. 120 in station lines ballasted to the top level.	60 and more when special expansion devices are used.	120-60-45 according to whether the annual temperature variations are : $\leq 20° \leq 30° < 40°$	ribbed sole plates and indirect fastenings.	100 m long rails used in the open with special expansion devices.
				in addition to 30 m, welded on site by the alumino-thermit process.					
ITALY : *State*	46.3	36	36—48	36 — 48	36	single rail with special expansion devices.	single rail with three standard rails at the ends : N° 2 of 36 m. N° 1 of 72 m.	sole plates with indirect fastenings.	Use of 48 m long rails as standard practice. Use of a single rail on masonry viaducts and metal bridges fitted with special expansion devices.
	50.6	36	—						
	49.05	36	36	welded by the alumino-thermit process on site and in the shops.					
PORTUGAL : *Portuguese Cy*	45	18	36	36	36	single rail with special expansion devices when more than 72 m (236' 2 3/4") long.	234 with 54 m long rails at the ends.	Without sole plates, fastened directly to the sleepers except at cross overs.	It is proposed to use welding to make 54 m long rails.
SWEDEN : *State*	50	20	20 -- 30	30	60	207 the type of joining was not defined.	20-60-920-60-20	Direct fastening with sole plates and elastic clips.	Insufficient experimental data available as regards very long rails.
	50								
	43.2								
SWEDEN : *Private*	43.2		40	40	40	40 standard joining.	—	Direct fastenings with sole plates and three coachscrews.	The length of 40 to 60 m represents the best choice to obtain comfortable running of the trains and reasonable maintenance costs.
				autogenous welding of new rails in the shops before laying.					

hard rock with great strength and durability is recommended.

The granulometric composition of the ballast in the case of the Italian State Railways lies between 30 and 60 mm (1 3/16″ and 2 3/8″) and in Austria between 35 and 70 mm (1 3/8″ and 2 3/4″).

The Italian State Railways however are considering the more general use of smaller ballast, especially in the case of the top layer of ballast used when tamping the sleepers.

8. *Give the arrangement adopted at the end of the rails, ordinary or special fishplates, special expansion devices, and describe them, especially in the case of bridges.*
Please give drawings and photographs.

8. In the case of track laid with the very long rails mentioned under questions 1 and 2 above, the Railways use the standard joints already described in Part I.

Apart from the Swedish Railways, the other Railways using longer than standard rails on bridges (up to 60 m = 196′ 10 1/4″). make use of special expansion devices.

In this case, the rails are welded over the whole length of the metal bridge lying between two fixed supports.

The special expansion devices used in Italy and Austria consist of a blade and stock rail both of which can slide together with their supports; the blade and stock rail are in contact with each other over a curved surface; they can be made to work with maximum expansions of 100 mm (3 15/16″), 200 mm (7 7/8″), or 400 mm (1′ 3 3/4″) (Cf. the drawings given in Fig. 17).

The Italian State Railways also have in service similar special expansion devices, but of a less recent type.

The Portuguese Railways do not give any details of the devices they use.

The Swedish Railways gave the following information : they have installed special anti-creep devices (4 pairs) and stops on the joints (3 pairs) to prevent the bolts breaking when, owing to the temperature, the joint gaps exceed the maximum of 20 mm (25/32″).

9. *Do you use any special devices to anchor the track to the bed? If so, please describe them.*

9. Up to the present, no special devices to anchor the track to the bed in the open have been used.

10. *At what temperatures are laid the very long rails dealt with in Question 3, and what regulations have been adopted concerning laying them?*

10. There is a widespread opinion amongst the Railways that very long rails in the open should be laid at a temperature lying between 5° and 30° C (41° and 86° F); the temperature of 30° should not be exceeded because above this limit, the joint gaps are closed right up.

See the second paragraph of Part III.

The same method is followed in the case of very long rails fitted with special expansion devices on metal bridges.

In tunnels, the Railways are agreed that the rails should be laid with the ends in contact, or with a gap of 2 mm (5/64″), according to convenience.

The Italian State Railways for 50 m (164′ 1/2″) inside each end of tunnels lay the rails with the same joint gaps as in the open.

11. *What are the maximum stresses allowed in these very long rails in the open?*

11. The Italian State Railways are of the opinion that on the open line a maximum axial compression stress of about 50 tons for each 46.3 kg at a temperature of 60° C is admissible. No abnormal stresses will occur with such joints as regards the tension strain, for the temperatures in question below zero (—10°).

The Swedish Secondary Railways are of the opinion that a tension strain should be allowed in the joints, starting from — 10°, so that at — 30° it will reach a value of about 28 tons for each rail.

The device mentioned under 8 above is used to resist this stress.

The other Railways did not give any

information; we believe the Austrian Railways are of the same opinion as the Italian State Railways.

12. *Have you experienced any abnormal creep with these very long rails?*

12. In general no abnormal creep has been experienced with very long rails in the open if the fastenings are of an efficient type, and sufficient anti-creep devices have been used.

In any case, there is less creep with very long rails than with short rails, owing to the reduction in the dynamic stresses occasioned by wheels passing over the joints.

13. *Have you experienced any vertical deformation of the track? or transversal?*

13. With the exception of the Swedish Railways, the Railways agree that they have not experienced any vertical or transversal deformation with very long rails in the open, when the tamping of the sleepers has been efficiently carried out and broken stone ballast is used up to the flange of the outer rail.

However the Italian State Railways have observed deformations in very hot weather, due to neglecting to take the above precautions, and a lowering of the strength of the track (abnormal closing of the joint gaps, too loose a bed after many single

Fig. 18. — *Italian State Railways.*
Displacement of the track.

sleepers had been replaced, unsuitable, non-permeable ballast).

These deformations occurred on curves of small radius after passing trains had caused the track to rise and then become displaced laterally.

14. *Have you carried out any experimental studies to determine the value of the stresses in the rail, the resistance of the rail fastenings on the sleepers and of the sleepers on the ballast with very long rails? If so, please give a complete description, with drawings, photographs and any useful graphs available.*

14. The Railways have not carried out any such experimental studies to determine the value of the stresses in the rail, the resistance of the rail fastenings on the sleepers and of the sleepers on the ballast with very long rails in the open.

The Italian State Railways have carried out experiments to determine the resistance of the track compared with spontaneous displacements of rails subjected to electric heating (see second paragraph of the third part). (Please see the photograph No. 18).

15. *Have you made any trials of very long rails on your main lines (apart from the standard user mentioned previously)?*
— *Give the number and characteristics of these trials;*
— *Describe the special devices used, especially at the ends of the rails;*
— *Give the observations made, the special maintenance measures involved, the special precautions that had to be taken when laying them, and in their inspection and maintenance.*

15. The Italian State Railways have carried out trials of very long rails on their main lines, apart from the standard examples given under 2 above :

a) Two 72 m (236′ 2 3/4″) long rails, using 240 sleepers with 50.6 kg (111 1/2 lbs)/m rails.

An invert of wooden sleepers was laid in the middle of each section to increase the solidity of the central supports.

The joints were of the standard type (angle fishplates), (see Fig. 19).

The trials were made over a period of 4 years (1939-1943).

No drawbacks were observed. At a temperature of 36° C (96.8° F) the joint gaps were closed and at — 10° C the gap was only 18 mm (45/64″).

b) A single length 425 m (1 394′ 4 1/4″) long consisting of 36 m rails welded together (46.3 kg/m rails) laid on a masonry bridge, with direct fastenings to enable the rails to move. .In the middle of the section, for 36 m in addition to the indirect fastenings to the supports and a corresponding invert, guide plate-stops at 9 supports were provided; at the ends of the section, special expansion devices were fitted to enable the joint gap to open as much as 200 mm (7 7/8″) (see Fig. 20).

This section which was completed in 1939 was destroyed in 1943 during the war.

The results had been entirely satisfactory.

The Swedish Secondary Railways have been carrying out a trial since 1935 of a single section 1060 m (3497′ 8 1/4″) long with rails welded together by the alumino-thermit process.

The fastenings (sole plates with wood packings and coachscrews) are the standard ones.

To overcome stresses due to the very low temperatures, 24 pairs of anti-creep devices were fitted.

The track was ballasted approximately up to the running surface of the rails.

On curves, to prevent lateral displacement of the track, pieces of rail (1 m = 3′ 3 3/8″) long have been set in the bed every 4 sleepers apart in contact with the rails.

The track is inspected every two years and sleepers replaced every 5 years.

At the same interval the unprotected metal surfaces are repainted with anti-rust varnish.

The track and the ballast have been made to stand up to frost.

No drawbacks due to the temperature have been experienced.

Apart from the above trials, carried out

on a main line, the Austrian Railways have laid 120 m (393′ 7 3/8″) long rails on station sidings, with standard fastenings. They have taken care to ballast the track up to the level of the rail head.

The Italian State Railways have also laid a station siding with 276 m (905′ 6″) long sections made of welded 46.3 kg rails, with indirect fastenings and special expansion devices at the ends.

During the whole period (two years), no variations were noted in the length of the central area (50 m long) owing to temperature changes, and the maximum variation at the ends was 40 mm (1′ 9/16″).

No drawbacks were experienced and the maintenance has been the same as for other service sidings.

16. *What conclusions have you drawn and what are your intentions regarding the use of very long rails on main lines with very heavy traffic, and generally speaking your views on the future of this question?*

16. The general opinion is that the use of very long lengths of welded rails in the open does not occasion any serious difficulty, likely to compromise the safety of the working by upsetting the stability of the track. Naturally, this applies to track laid with indirect fastenings which assure perfect adhesion between rails and sleepers, completely covered with broken stone ballast; in every case the track must be carefully maintained.

The Austrian Railways would like to use 100 m (328′ 1″) long rails, with special expansion devices.

The other Railways, however, in particular the Italian State Railways, have experienced, by the use of very long rails, difficulty as regards the handling and maintenance.

The above considerations lead us to make the suggestion that a certain length of rail should not be exceeded so that the standard joints can still be used at longer intervals, without any exceptional maintenance measures being necessary.

In this connection, the Italian State Railways, taking their own climate into account, recognise that they can use 48 or 54 m (167′ 5 3/4″ or 177′ 2″) long rails.

The Portuguese Railways would like to use 54 m long rails and the Swedish Secondary Railways recommend rails between 40 and 60 m (131′ 2 3/4″ and 196′ 10 1/4″) long.

In this connection the Swedish Secondary Railways remark, that from the results obtained with a trial carried out during 15 years on a 1060 m long section, it would appear that though no prejudice was caused to the safety of the working, maintenance costs were greater with such a length.

The standard use of greater lengths of rail than the above has an ample field in the case of bridges and tunnels.

***

PART III.

Expansion gaps. — Determination of standard allowances.

1. *Give a table showing the joint gap in terms of the temperature for the different types and lengths of rails.*

Make it clear whether the temperature concerned is that of the rail or the atmospheric temperature, and state how it is measured.

1. Table VII gives the joint gaps allowed for the different rail lengths, taking into account variations in the temperature.

On mountain lines, on which the temperature is commonly very low, the Italian State Railways decided to reduce the joint gap still more by 1 mm (0.039 in.) in the case of 9 — 12 and 18 m (29′ 6 3/4″ — 39′ 4 1/2″ and 59′ 5/8″) long rails, by 2 mm (0.078 in.) in the case of 36 m (118′ 1 1/4″) rails and by 3 mm (0.118 in.) in the case of 48 m (157′ 5 3/4″) long rails.

The Portuguese Railways and the Swedish Secondary Railways do not make it clear if the temperatures given in their replies are those of the rails or the atmospheric temperature. The other Railways use rail thermometers to measure the temperature.

The Italian State Railways measure these temperatures by means of a case (in which

TABLE VII.

Expansion allowances.

AUSTRIA : *Federal Railways.*

Rail temperature	for rails of m				
	10	15	20	30	60
30	0	0	0	0	—
29÷ 26	1	1	1	1	—
25÷ 23	1	1	2	2	1
22÷ 20	1	2	2	3	3
19÷ 17	2	2	3	4	4
16÷ 14	2	3	4	5	7
13÷ 11	2	3	4	6	9
10÷ 8	3	4	5	7	11
7÷ 5	3	4	6	8	13
4÷ 0	4	5	7	10	16
— 1÷— 5	4	6	8	12	20
— 6÷—11	5	7	9	13	—
—12÷—17	6	8	10	15	—
—18÷—23	6	9	12	17	—
—24÷—30	7	10	13	20	—

ITALY : *State Railways.*

Rail temperature	for rails of m				
	9	12	18	36	48
33÷ 30	0	0	0	0	0
29÷ 26	0	0	1	1	1
25÷ 23	0	1	1	2	3
22÷ 20	1	1	2	3	5
19÷ 17	1	1	3	5	7
16÷ 14	1	2	3	6	9
13÷ 11	2	2	4	7	10
10÷ 8	2	3	5	8	12
7÷ 5	2	3	5	10	14
4÷ 0	3	4	6	12	—
— 1÷— 5	3	4	7	13	—

PORTUGAL : *Portuguese Railways Cy.*

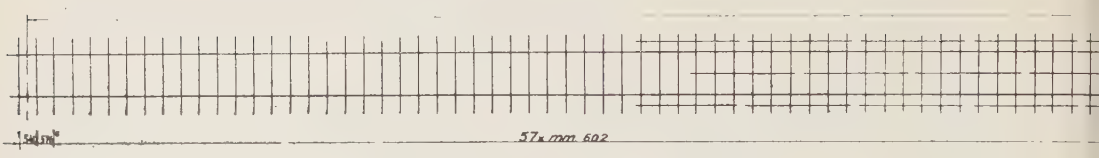
Rail temperature	for rails of m		
	8	12	18
> 30	3	3	4
30 ÷ 20	4	5	6
19 ÷ 10	5	7	9
9 ÷ 0	6	9	12

SWEDEN : *State Railways.*

Rail temperature	for rails of m				
	7÷9	9÷10	10÷15	15÷22	22÷30
>31	2	3	3	4	4
30÷ 16	3	4	4	5	5
15÷ 6	4	5	6	7	8
5÷— 4	5	7	8	9	10
— 5÷—15	7	9	10	11	12

SWEDEN : *Private Railways.*

Rail temperature	for rails of m	
	20	40
>30	—	3
30÷ 25	—	5
24÷ 20	—	7
19÷ 15	—	9
14÷ 10	—	11
9÷ 5	—	13
4÷ 0	—	15
— 1÷— 5	—	17
— 5÷—10	—	20



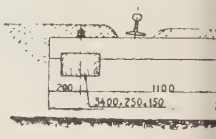


Fig. 19. —
Lengths of 72 m on 12

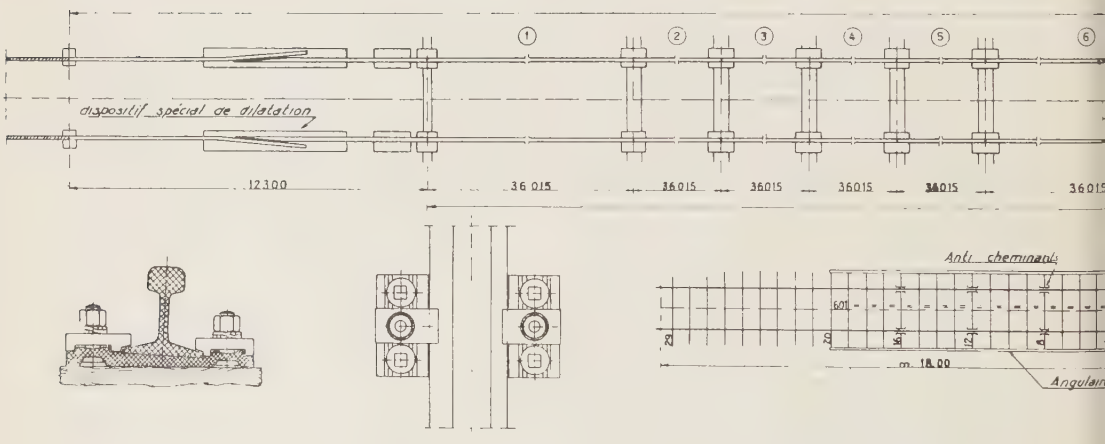


Fig. 20. —
Single length of 425 m made up of 36 m long rails

the thermometer is fixed), which is applied to the head of the rail for 10 minutes; adhesion is assured by a magnet.

In this way the thermometer is not affected by the rays of the sun.

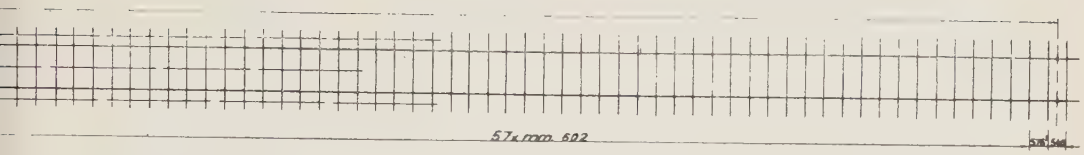
2. *Explain how these regulations were determined.*

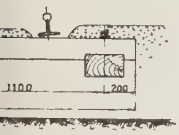
a) *Are they the result of special experiments carried out with this object?*

If so, describe these experiments, giving full details about the constitution of the track, rails, sleepers, ballast, method of fastening the rails on the sleepers (indirect or otherwise), the use or not of anti-creep devices, etc...;

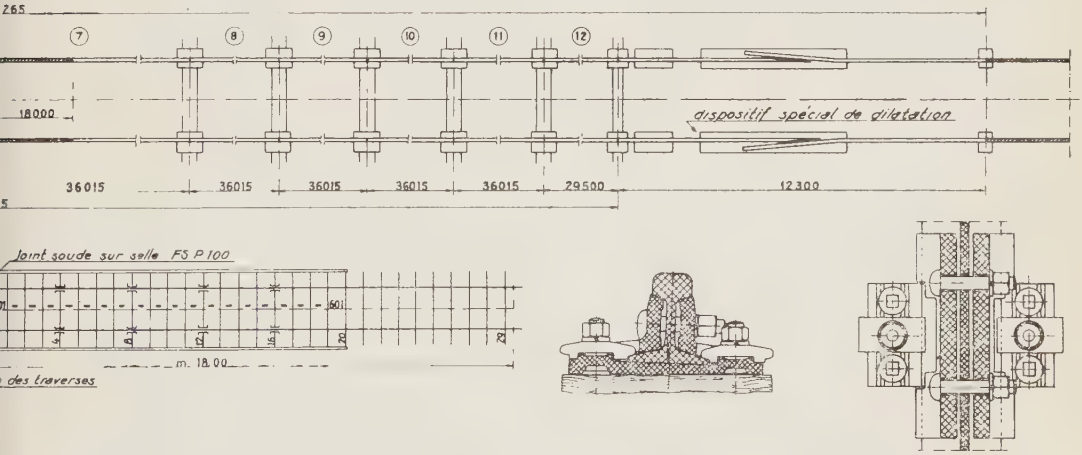
b) *Are they the result of observations made on the line under normal working conditions?*

If so, give full details of the field covered by these observations, number of cases, kind of line, traffic, etc...;





Railways.
with 50.6 kg/m rails.



Railways.
gether (46.3 kg/m rails) laid on a masonry bridge.

Give particulars as in a) *above of the track concerned;*

c) *Are they the result of calculations taking into account not only the free expansion of the rail, but also the possibility of admitting stresses?*

Have you noted any divergence between the results of these calculations and the actual observations made on the track under working conditions?

2. The Railways have long since given up the criterium of free expansion of the rails and have gone in for the very complex phenomena of limited expansion in which account must be taken of the influence on the resistance of the creep of the track on the ballast, and on the resistance of the fastenings owing to physical variations in the rails due to thermic effects.

The Portuguese and Swedish Railways have stated that the values of the joint gaps

are determined by experience acquired on the line under normal working conditions with very heavy traffic, i. e. lines having more or less similar characteristics to those with which this report is concerned.

The Italian State Railways, and Austrian Railways remark that the value to be given to the joint gap has been determined by calculation.

According to the Italian State Railways the joint gaps (paragraph 1) were calculated taking into account the well known theory of the limited expansion of the rails.

In making these calculations the Italian State Railways gave a value of 6 kg/cm of rail to the frictional resistance between the sleeper and the ballast, and allowed for the possibility of allowing a maximum longitudinal compression of about 50 tons for each rail, when the maximum temperature observed on these lines during the summer is reached.

According to the Austrian and Italian State Railways the temperature are chosen in such a way that the rails can be put into service without internal stress, at the temperature of the rail lower to 30° C (86° F) approximately.

Consequently they should not be laid when the temperature is higher than this, and if necessary the next day in the early morning, the fastenings should be undone and the rails moved to rectify the joint gaps and make them the correct size.

The Italian State Railways established the above value of 6 kg from observations made on the thermal expansion of rails in trial sections on lines in normal operation.

The track was laid with rails of a weight of 46.3 and 50.6 kg/m 18 and 36 m long either with indirect fastenings throughout or with a certain number of direct fastenings here and there, on broken stone ballast.

The line in question was a double track line run over by heavy passenger and goods trains, with very heavy traffic throughout the day.

Observations were made at given hours of the day, over a 24 hour period, to obtain a continuous cycle for the rising and falling temperatures of the rail.

The data collected in this way were used to determine the frictional resistance between the sleeper and the ballast from the formulae of the preceding theory.

Having repeated these observations several times at different seasons, over a long period of time (1934 to 1943) the Italian State Railways were able to decide the average value, which is sufficiently close to the actual conditions.

In addition, as regards the longitudinal compression stress of the track, the Italian State Railways, were able to allow for the internal stresses, taking into account the fact that on the lines in question broken stone ballast covered the sleepers both on the sides and on the upper part, as shown in Fig. 21.

Lines equipped in the above manner have a very strong resistance to deformation due to longitudinal compression stresses; all the experiments carried out on lines under normal working conditions have confirmed this conclusion.

The object of the experiments made was to determine the deformation of the track, caused by electrically heating the rails by means of special equipment.

Although the track was not subjected to stresses due to the passage of the dynamic loads of trains, a longitudinal compression stress of about 240 tons was measured after increasing the temperature to 130° C (266° F) before any displacement of the track was observed.

Consequently it can be affirmed that safe operating conditions are obtained with the compression values selected.

The trial track was equipped with rails 30 m long 49.05 kg/m laid on supports spaced about 60 cm (1′ 11 5/8″) apart, sole plates with indirect fastenings, wooden packing plates inserted between the sole plate and foot of the rail, and broken stone ballast.

The experimental section which was on a double track line with important traffic, was worked as a single track line during the trials.

The Austrian Railways as well as the Italian State Railways state that their very long experiments prove that there is agreement between the joint gap as calculated

and the observations made on the track in service.

The same Railways have verified the fact that during periods of high atmospheric temperature, the opening of the joint gap at a given temperature is greater than it was when the rail was laid, whereas on the contrary during the period of falling temperature, the gap was smaller than the gap when the rail was laid.

This is due to the efficacity of the frictional resistance between the sleepers and the ballast.

The Italian State Railways kept a regular record of the rail temperatures on their lines during the summer of 1949, which was particularly hot, and verified the fact that owing to the small difference in temperature between day and night, the temperature of the rails remained very high, the maximum temperature occurring about two hours after midday. It was also found that the maximum temperature of 60° C (140° F) introduced as the upper limit in the calculations to determine the value of the joint gap was not reached.

So as not to decrease the safety margin for the track, it was considered prudent to suspend work and put off maintenance operations during very hot periods.

The adoption of very small joint gaps, which is in conformity with the favourable results obtained under actual operating conditions, becomes absolutely necessary in view of the tendency to go in for ever increasingly long rails; consequently the heavy hammer blows which occur at the joints when vehicles pass over them at speed, especially on double track lines, determine the longitudinal creep of the rails, which pile up and consequently almost cancel out the joint gap allowed.

Consequently in the case of well anchored track subjected to a considerable amount of friction on the ballast, owing to the wide spacing of the joint gaps, it is impossible to prevent the formation of burrs at the ends of the rails, abnormal wear of the fishplates bearings, broken fishplates and rails, and above all the necessity for very frequent and costly maintenance of the joints.

Experiments carried out over 10 years prove that the resistance to rail creep on the metal sole plates plays a very important part in the expansion of the rails, by increasing the resistance to creep of the track between the under side of the sleepers and the ballast; for this reason the Railways have attached great importance to indirect fastenings which prevent the creep of the rails, by making all the track equipment play its part in the surface friction with the ballast, and consequently there is a very definite tendency to increase the length of the rails ever further.

Fig. 21. — *Italian State Railways.*
Section of ballast.

3. *Please give the tolerances allowed for the joint gaps on the running line.*

3. Apart from the Austrian Railways who consider it necessary to adhere very strictly to the values laid down for the joint gaps; the Portuguese Railways give tolerances of ± 5 mm (13/64″), which in our opinion is too much, and the Swedish Railways did not give any details on this subject.

However, the Italian State Railways remark that when operating a line that has been laid with the standard joint gaps, it is not possible to carry out a rigorous control since in the rails in service there may be old locked in stresses, due to the daily

variation in the thermic cycle which affects their physical condition.

Consequently it is not possible to lay down a tolerance value between each joint gap occurring on the track in service and those laid down in the technical regulations.

However, it must not be forgotten that there is a factor that tends to modify the uniform distribution of the joint gaps in a section of line, i. e. longitudinal creep of the rails; for this reason variations between individual joint gaps should not be taken into account, but rather the uniformity of the values of the gaps over the section in question.

Only by taking into account this uniformity of the values is it possible to consider what the tolerance should be, taking it that the variation between all the values of the joint gaps in the section of track in question may be as much as 1 — 3 mm according to the length of the rails in service.

This tolerance can, without doubt, be compensated by the important margin of safety which exists between the stress allowed in the track when regularly laid, and the stress required to determine buckling. However if the above tolerance is exceeded, it becomes necessary immediately to correct the gaps and restore them to the average value for that section of line, moving the rails as required and if needs be using anti-creep devices.

However, to increase the margin of safety it is possible to take into account the variation between the average joint gap in the section of line at a given temperature and the value laid down in the technical prescriptions for the same temperature, and if this difference should exceed the said tolerance in the negative sense, the gaps must be corrected and all the rails restored to their regular positions.

4. *What steps do you take when the tolerances are exceeded to restore the correct joint gap?*

4. The Austrian Railways stated that each year, before the hot weather begins (preferably when the rail temperature is 5 degrees) it is prescribed in the regulations that the joint gaps between given points (metal bridges, track equipment) shall be measured with a measuring gauge.

If the gaps show great variations in comparison with the theoretical values, they must be corrected.

This compensation is carried out by restoring the joints to the average value of all the gaps measured (arithmetical or graphical average).

The correction of the gaps starts from the first fixed point towards the second in the direction of longitudinal creep of the track, pulling back the rails as necessary with the equipment provided for this purpose.

Care must be taken to regularise the gaps at any joints that have closed up or where the gaps are too small when the temperature of the rails is low or falling; to correct any gaps that have become too large when the temperature is rising. The operation must be carried out by taking off the fishplates and inserting expansion wedges.

The above regulations, naturally, only apply when the track in the section of line under consideration were originally laid with very strict application of the prescribed values for the joint gaps; in other cases the gaps must first of all be corrected to restore the track to the prescribed technical conditions.

[625 .143 .4]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION II.

Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps : determination of standard allowances.

REPORT

(America (North & South), Burma, China, Egypt, Great Britain and Northern Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan),

by P. Croom-Johnson, C.B.E., M.I.C.E.,

Chief Engineer, London Transport Executive, London.

FOREWORD.

Copies of the questionnaire were circulated to 26 railway administrations from whom, at the latest date for the submission of this report, only 8 fully detailed reports had been received. These are reviewed in the report and summarised in the appended tables Nos. 1 to 10.

The information received on improvements to fishplated joints and on expansion gaps relates to flat-bottom rail, except in the case of the London Transport Executive whose experience of flat-bottom rail has been limited to short test lengths installed for experimental purposes during recent years, and who have given their information in relation to bull-head rails.

It should be noted that British Railways have only recently adopted flat-bottom rail as their standard for renewals. This comprises special sections of 98 lbs. and 109 lbs. per yard. The London Transport Executive are also proposing to adopt this standard, to an extent to be determined by experience.

Information on long welded rails has been offered by 5 railway administrations only, others stating either that their use of welded rails has not been sufficient to warrant a detailed reply to the questionnaire, or that they possess little or no experience of the subject.

(A). — Rail joints : Improvements in fishplated joints.

(1) *Give particulars of the rail or rails concerned, also cross sectional drawing, with the principal dimensions and the weight in pounds per yard or in kilogrammes per metre.*

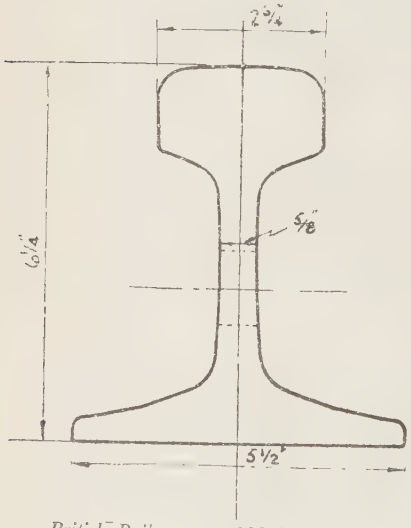
Answer. — See Table 1.

Certain administrations use more than one section of rail. Considering the administrations as a whole, the rails utilised

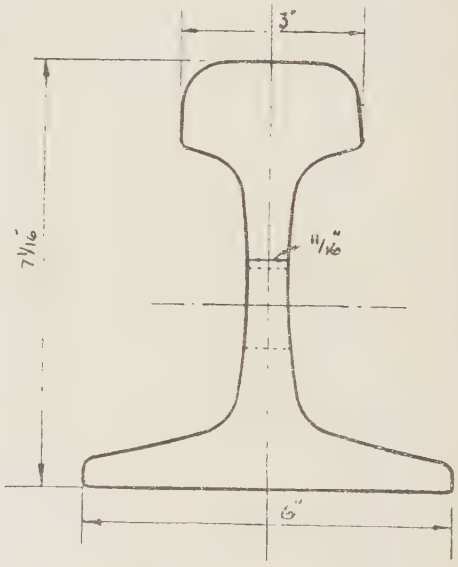
cover a large range in weight per yard, varying between 46 1/4 and 155 lbs.

For the purposes of this report, however, only rails of 80 lbs. or more in weight per yard have been considered. The heaviest rail in use is the 155 lbs. per yard flat bottom section on the Pennsylvania Railroad which administration also uses rails of 140 lbs. and 133 lbs. per yard. It is interesting to compare the latter section with the newly designed 109 lbs. flat bottom rail section recently introduced on British Railways, (see Figure 1).

Sleepers both of wood and steel are used, and the Government of India Railways also use cast iron sleepers on certain sections. Joints are generally suspended between sleepers but the Pennsylvania Railroad prefers a single sleeper placed immediately under the joint, with adjacent sleepers spaced 10″ away on each side. The South African Railways are experimenting with joints resting on twin wood and steel sleepers and the Government of India Railways have joints supported on cast iron pot type sleepers on some sections.



British Railways. — 109 lbs. rail.



Pennsylvania Railroad. — 133 lbs. rail.

Fig. 1.

The section of the heavier U. S. A. rail 155 lbs. per yard, can broadly be said to follow the design of the 133 lbs. rail illustrated in Figure 1, with a general increase of dimensions, except that the width of the head remains constant at 3″.

(2) *State whether the sleepers are of wood or of steel and describe their arrangement adjacent to the joint. Is the joint carried on a single sleeper, or on close or coupled sleepers, or is it suspended between sleepers?*

Answer. — See Table 1.

In no case has reference been made to any special arrangement of sleepers such as coupled sleepers, at or adjacent to the joints, in general use. The practice once obtaining in Great Britain of using short 2—hole fishplates in combination with close sleepering has now been discontinued.

(3) *Are the rail joints opposite to one another or staggered (alternating) in position?*

Answer. — See Table 1.

Joints are usually placed opposite to one

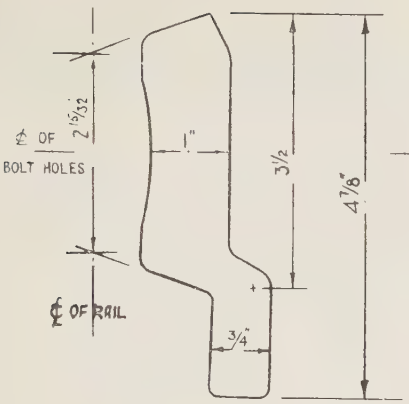


Fig. 2. — *London Transport Executive.*
Fishplate for 95 lbs. B.H. rail.
Area = 9.25 □″ Length = 18″

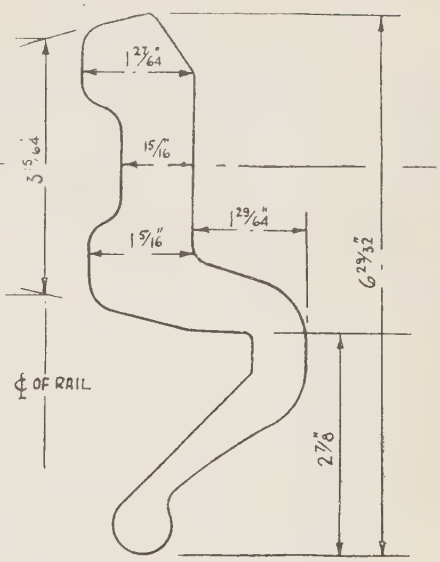


Fig. 3. — *South African Railways.*
Fishplate for 96 lbs. rail.
Area = 14.6 □″ Length = 18″

another. The Pennsylvania Railroad, however, staggers the joints, those on one rail being situated opposite the middle of the other rail. The Government of India Railways employ staggered joints on curved track and the South African Railways have staggered joints under test.

(4) *What is the maximum and minimum width of the sleepers at joints and of those adjacent to the joint sleepers?*

Answer. — See Table 1.

(5) *Describe the joints and supply dimensioned drawings.*

Answer. — See Table 1.

No radical differences in design are indicated in the replies received, the rail ends being square cut with normal 4—hole or 6—hole fishplate connections.

(6) *Supply particulars of the cross-section of the fishplates used — flat, angled, flanged, tailed or other types. Give reasons for choosing sections adopted. Give the area of cross section, moment of inertia and*

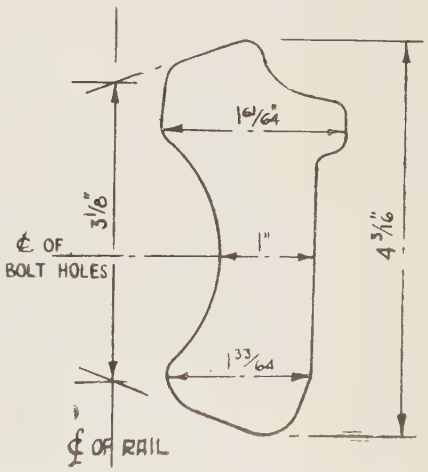


Fig. 4. — *British Railways.*
Fishplate for 109 lbs. rail.
Area = 10.08 □″ Length = 20″

TABLE 1. — **Rail joints**

Note : *The column headings only summarise the questions.*

Question	1. Type of rail			2. Joint sleepers			3. Rail joints	4. Size of
	Lbs. per Yd.	Height	Width foot	Material	Supported joint	Suspended joint	Position	At joints
Note : The particulars for British Railways relate entirely to flat bottom (Vignoles) rail, which is now standard								
British Railways (4′-8 1/2″ gauge)	109 lbs. per yd. flat bottom (98 lbs. also will be used - 113 lbs. to be discontinued)	6 1/4″	5 1/2″	Usually of Wood		Generally suspended-sleepers 2′ 1″ centres	Opposite	10″ × 5″
Note : The current general standard is flat bottom rail but the change is relatively recent and the particulars given								
London Transport Executive (4′-8 1/2″ gauge)	95 lbs. bull head	5.23/32″	2 3/4″	Wood		Suspended-sleepers 2′-2″ centres in open & 2′-0″ in tube tunnels	Opposite	Standard is 12″ but many 10″
Pennsylvania Railroad (4′-8 1/2″ gauge)	133 lbs. 140 lbs. 155 lbs. flat bottom	7.1/16″ 7.5/16″ 8″	6″ 6″ 6 3/4″	Wood	Sleeper under joint & one each side 10″ face to face		Staggered 19′-6″-39 ft. rails	7″ × 7″ to 9″ × 8″
South African Railways (3′-6″ gauge)	96 lbs. flat bottom	5 7/8″	5″	Wood & Steel	Experiments with joints resting on wood and steel sleepers	Suspended-sleepers 1′-8″ centres	Opposite but staggered joints 5′5″ 6′-11 3/4″ 9′-0″ & 60′-0″ apart are under test	10″ wide, wood 5″ wide at top 10″ wide at bottom for steel

improvements in fishplated joints.

For verbatim questions see pages 207/75 to 245/113.

sleeper	5. Description of joint	6. Fishplates per pair					
Adjacent		Type	Area (ins^2)	Moment inertia (ins^4)		Modulus Resistance (ins^3)	
				F. plates (pair)	Rail	F. plates (pair)	Rail
on all the lines although at present most of British Railway track is bull head type.							
10″×5″	For 109 lbs rail the fishplate is 20″ long with four pear-shaped bolt holes 1.1/16″ × 1 3/8″ at 5″ centres	Unsymmetrical 4.3/16′ 1.61/64″ designed for high strength-weight ratio	10.08	13.74	55.9	Head=6.65 Base=6.46	Head=16.89 Base=19.02
herein relate to the 95 lbs. per yard British Standard bull-head Rail.							
Standard is 10″ in open. 12″ standard in tube tunnels but many 10″	Fishplate 18″ long, four pear-shaped holes 1″×1.5/16″	Tailed 4 7/8″×1″	9.25	16.78	34.91	Head=7.04 Base=6.74	Head=12.12 Base=11.53
7″×7″ to 9″×8″	Fishplates 3′-0″ long but 3′-2 1/2″ long for 155 lbs. rail with 6 bolts. Holes are alternately round 1.3/16″ and elliptical 1 1/2″×1.3/16″	Unsymmetrical 5″×2″ to 5.13/16″ ×2.3/32″	11.4 (133 lbs.)	28.6	86.3	Head=11.5 Base=11.2	Head=22.3 Base=26.9
			13.6 (155 lbs.)	46.7	129.0	Head=16.4 Base=15.7	Head=28.7 Base=36.7
10″ wide wood 5″ wide at top & 10″ wide at bottom for steel	Standard fishplates are 1′-6″ long, four hole with holes in one plate 1.1/16″ diameter and elongated holes 1.5/16″ ×1.1/16″ in the other plate	Tailed 6.29/32″ ×1.5/16″	14.6	46.24	43.78	Head=14.34 Base=12.54	Head=14.29 Base=15.57

TABLE 1. — **Rail joints :**

Note : *The column headings only summarise the question.*

Question	1. Type of rail			Joints sleepers			3. Rail joints	4. Size of
	Lbs. per Yd.	Height	Width Foot	Material	Supported j oint	Suspended joint	Position	At joints
Government of India Railways (5′-6″ and 3′-3 3/8″ gauge)	50, 60, 75, 90 lbs. 115 lbs. flat bottom	5 5/8″ 6 3/8″	5 3/8″ 6 1/8″	Wood, Steel, Cast Iron.	On cast iron sleepers on some lines	Usually suspended-spacing 1′-7″	Usually opposite on straight & staggered on curves	10″ for broad gauge, 8″ for metre gauge (wood). Steel sleepers for 115 lbs rail. Width of rail-seat = 5″ bottom = 10 1/8″ depth = 3 1/2″
Nizam's State Railway (5′-6″ gauge & 3′-3 3/8″ gauge)	85 lbs. (also 50 lbs.) flat bottom	5.3/16″	5.3/16″	Wood and Steel		Suspended sleepers 1′-6″ centres.	Opposite, but in future relayings middle-staggered joints will be installed	10″ on broad gauge 8″ on metre gauge
Ceylon Government Railway	90 lbs. 88 lbs. 80 lbs. 72 lbs. 46 1/4 lbs. flat bottom	5.5/16″ 4 7/8″ 5″	5.5/16″ 5 1/2″ 5″	Wood and steel		Suspended-sleepers 2′-0″ centres	Opposite	—
Victorian Railways	60 lbs. 94 lbs. 107 lbs. flat bottom	4 1/2″ 5.9/16″ 6.3/16″	4 1/4″ 5″ 5 3/4″	Wood		Suspended-sleepers 1′-6″ centres	Opposite	10″ × 5″

ovements in fishplated joints. *(continued)*

verbatim questions see pages 207/75 to 245/113.

eper	5. Description of joint	6. Fishplates per pair					
djacent		Type	Area ins²	Moment inertia (ins⁴) F. plates (pair)	Moment inertia (ins⁴) Rail	Modulus resistance (ins³) F. plates (pair)	Modulus resistance (ins³) Rail
for broad ıge, 8″ for tre gauge od). Steel epers for 5 lbs. rail. th of rail- eat — 5″ ottom — 10 1/8″ epth — 3 1/2″	Fishplates for 90 lbs. & 115 lbs. rail=1′-6″ long, four hole, 1.1/16″ & 1.7/32″ diameter respectively.	Unsymmetrical	90 lbs. = 8.7 115 lbs. = 10.3	90 lbs. rail = 11.5 115 lbs. rail = 18.2	= 38.5 = 62.5	90 lbs. rail head = 6.0 base = 5.97 115 lbs. rail head = 8.58 base = 8.17	90 lbs. rail head = 13.05 base = 14.38 115 lbs. rail head — 18.5 base = 20.9
10″ 8″	Fishplate 1′-6″ long with four 1.1/16″ dia. holes, 6″ mid-centres and 4″ centres at ends.	Symmetrical 3.5/16″ × 1.3/16″	—	—	—	head = 3.09 base = 3.05 = 50% to 70% of rail	—
—	90 lbs. rail has fishplate 2′-2″ long, four 1.1/16″ dia. holes at 6″ centres. 88 lbs. rail fishplate is 1′-6″ long, four pear shaped holes 1.7/16″ × 1.1/16″ at 4 1/2″ centres. 80 lbs. rail fishplate is 1′-71/2″ long, four pear shaped holes.	(90 lbs. rail) Angle (88 lbs. & 80 lbs. rail) Flat.	—	—	—	—	—
10″ × 5″	60 lbs. rail has fishplate 2′-1″ long, four holes alternately round and elliptical, 15/16″ diameter and 15/16″ × 1.3/16″. Similar 6 hole fishplate 2′-6″ long. 94 lbs. and 107 lbs. rails have 4 hole and 6 hole fishplates with holes 1.1/16″ diameter and 1.1/16″ × 1.5/16″; both rails have bar type fishplates which in 4 hole plate is only 1′-8″ long.	60 lbs. rail Angle. 94 lbs. rail has both Angle and Bar. 107 lbs. = Bar	60 lbs. rail = 7.10 94 lbs. rail angle = 9.60 bar = 6.96 107 lbs. rail Bar = 9.28	60 lbs. rail = 7.06 94 lbs. rail angle = 13.1 bar = 7.86 107 lbs. = 15.08	60 lbs. rail = 16.57 94 lbs. rail = 38.26 107 lbs rail = 54.78	60 lbs. rail head = 3.58 base = 4.66 94 lbs. rail angle head = 5.86 base = 7.12 bar head = 4.16 base = 4.38 107 lbs. rail head = 7.20 base = 6.98	60 lbs. rail head = 7.16 base = 7.58 94 lbs. rail head = 13.29 base = 14.26 107 lbs. rail head = 16.56 base = 19.01

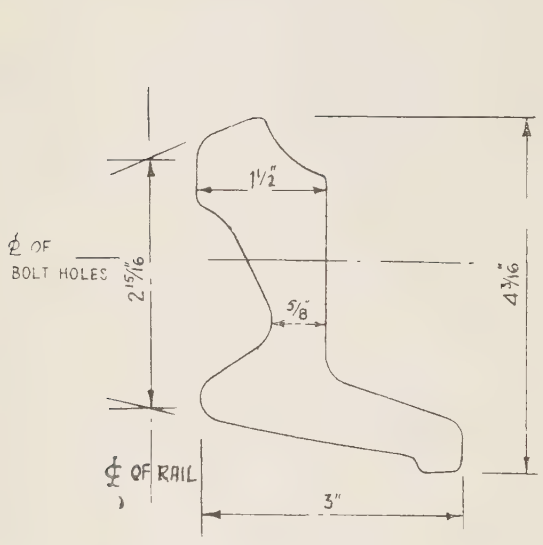


Fig. 5. — *Victorian Railways.*
Fishplate for 94 lbs. rail.
Area = 9.60 □″ Length = 25″ or 30″

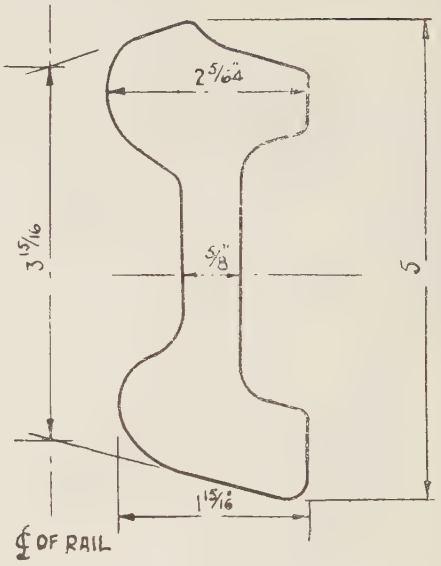


Fig. 6. — *Pennsylvania Railroad.*
Fishplate for 133 lbs. rail.
Area = 11.4 □″ Length = 36″

modulus of resistance. How do these values compare with the corresponding figures for the rail?

Answer. — See Table 1.

Considerable attention has been given, and continues to be given, to the design of fishplates, with a tendency either towards redesigning the fishplates for use with existing rail sections, or towards a revision of both rail and fishplate sections, to provide a stiffer and stronger support at the joint.

Cross sections are given of 5 of the more modern designs of fishplate; Figures 2 and 3 illustrate modification of design for use with existing rail sections; whilst Figures 4, 5 and 6 illustrate designs evolved in conjunction with new rail design.

Comparison of the section moduli of the fishplates illustrated are given in the following table together with their values expressed as a percentage of the modulus of the rail to which they apply :

	British Railways	*London Transport*	*Victorian Railways*	*Pennsylvania Railroad*	*South African Railways*
Fishplates	6.65 ins³	7.04 ins³	5.86 ins³	11.5 ins³	14.34 ins³
Rail	16.89 ins³	12.12 ins³	13.29 ins³	22.3 ins³	14.29 ins³
Ratio	39 %	58 %	44 %	52 %	100 %

The wide variation in the ratio between fishplate and rail strengths is to be noted. No reason is given for the choice of the particular fishplate section adopted.

(7) *Describe the longitudinal form of the fishplates generally, and refer particularly to any special characteristics. Does the fishplate bear along the whole of its length on the fishing angles of the head and foot of the rail?*

Answer. — See Table 2.

The lengths of the fishplates vary from 1′—6″ to 3′—2 1/2″. All replies refer to the normal practice of providing a bearing for the full length of the fishplate. The South African Railways indicate that tests are being conducted with fishplates having bearings at the centre and at the ends, at the top and bottom respectively.

For details of fishplate lengths see Table 1.

(8) *What is the slope of the fishing angle at the head and at the foot of the rail? Does the fishplate bear on the full width of its fishing angle? Is any machine surfacing as grinding or milling of the fishing angles carried out? Please give reasons for the practices adopted in relation to these three points.*

Answer. — See Table 2.

There is a wide variation in the fishing angles adopted by different administrations but, with the exceptions of the Pennsylvania Railroad, the Victorian Railways and the Government of India Railways, all administrations adopt equal fishing angles top and bottom. British practice favours an angle of 20°, the aim in design being to obtain the same fishing angles at the head and foot of rail as a preventive against unequal wear of fishing surfaces and the cocking of fishplates.

On the other hand, an angle of approximately 14° top and bottom is used by three administrations as a result of past experience, and as giving a reasonable draw and facilitating good rolling.

The Pennsylvania Railroad adopts a top angle of 18 1/2° with a bottom angle of 14°. The Government of India Railways employ a top angle of 18 1/2° in combination with a bottom angle of only 9 1/2°. The Victorian Railways employ a top angle of 18 1/2° and bottom angle of 11 1/2°. The Pennsylvania Railroad states that when angles of lesser degree were used in the past there was a tendency for the fishplate to become wedged, thus producing a frozen joint which contributed to excessive batter at rail ends, and that extreme care had to be exercised to avoid a cocking of the fishplate and a deformed joint.

Whilst the actual width of bearing surface varies, all administrations make use of the full available width of bearing surface.

No grinding or machining of fishing angle surfaces is carried out, the view being held that for general purposes the cost is not justified.

(9) *Give particulars of the position and spacing of the fishbolt holes in the rail. Is the location of the holes related to the placing of the fastening of the rail to the sleeper?*

Answer. — See Table 2.

The position and spacing of fishbolt holes in the rail mostly follow the general pattern of the first hole being from 2 1/8″ to 2.7/16″ from the rail end with the next hole being spaced 4 1/2″ from the first. The Pennsylvania Railroad uses a heavy six hole fishplate, 3 ft. long in which the second and third holes are placed 6″ and 7″ respectively from the preceding hole. In no case is it stated that the position of the holes and rail fastenings are correlated.

(10) *What difference in level, on account of wear, is permitted between the running surfaces of the two rails at a joint? When these differences exceed the amount allowed, what methods, for example, linings or special fishplates, are utilised for correction?*

Answer. — See Table 2.

QUESTIONS	7. Fishplates-longitudinal section		8. Fishing angles		
Railway	Characteristics	Bearing of fishplate	Slope of fishing angle	Width of bearing head & foot	Machini of fishing surf
British Railways	Same fishing angles top and bottom Area of contact as large as possible	Full width contact throughout length of fishplate	20° head and foot	5/8″	Not consid justifie for gene purpos
London Transport Executive	Same fishing angles top and bottom	Full width contact throughout length of fishplate	20° head and foot	5/8″ to 3/4″	No machi of fishplat for normal tr
Pennsylvania Railroad	Flatter fishing angle at bottom	Full width contact throughout length of fishplate	18 1/2° head 14° foot	9/16″ & 1.9/64″ : 133 lbs. 19/32″ & 1.9/64″: 140 lbs. 31/64″ & 1.23/64″: 155 lbs.	None
South African Railways	Same fishing angles top and bottom	Full width contact throughout length, but fishplates on test with bearing top centre and bottom ends	1 in 4 head and foot (14°)	5/8″ top 1″ bottom	None
Government of India Railways	Flatter fishing angle at bottom	Full width contact throughout length of fishplate	1 in 3 head = 18 1/2° 1 in 6 foot = 9 1/2°	90 lbs. rail 3/4″ top 1 1/8″ bottom 115 lbs. rail 3/4″ top 1 1/4″ bottom	None
Nizam's State Railway	Same fishing angles top and bottom	Full width contact throughout length of fishplate	1 in 4 head and foot = 14°	5/8″	None
Ceylon Government Railways	Same fishing angles top and bottom	Full width contact throughout length of fishplate	1 in 4 head and foot =14°	90 lbs. rail 11/16″ top 7/8″ bottom 88 and 80 lbs. rail 5/8″	—
Victorian Railways	Flatter fishing angle at bottom	Full width contact throughout length of fishplate	1 in 3 head = 18 1/2° and 1 in 5 foot = 11 1/2°	60 lb. 1/2″ top 1″ bottom 94 lb. angle 1/2″ 1 1/4″ 94 lb. bar 5/8″ 1″ 107 lbs. 5/8″ 1″	None

9. Fishbolt holes in rail			10. Rail surface level at joints		11. Rails rolled together laid abutting in track
om nd rail	Centre to centre of holes	Arrange-ment in relation to rail fastening	Permitted differences	Correction (adjustment) methods	
3/8″	5′	Independent	No precise limit, but seldom more than 1/32″	« Lift » fishplates or reconditioned fishplates, or shims	Depth and fishing angles matched as far as possible
3/8″	4 1/2″	Independent	1/32″	Metal shims or « lift » plates	No special measures to this end
3/32″	6″ & 7″	Independent	No precise limit	Oversized fishplates or welding	Normally same rolling laid together
1/8″	4 1/2″	Independent	No precise limit	If exceeding 1/32″ difference the low rail end is welded	Not specially batched according to rolling, but in practice uniformity is general.
1/8″	4 1/2″	Independent	No precise limit	Shims used for differences of 1/16″ and over	Yes, when new rails are used
7/8″	4″	Independent	Kept level	—	—
7/8″ 6″ (88) 6″ (80)	6″ 4 1/2″ 5″	Independent	No standard	Linings	No
7/16″	5″	Independent	No difference permitted	To correct any discrepancy, rail end built up by welding	Where practicable rails are placed in order of rolling, but no special attempt is made to match rails

No precise limit is generally laid down as a maximum permitted difference in level of the running surfaces of two rails at a joint due to wear. One administration however refers to a maximum permissible difference of 1/32″ whilst another administration states that in practice a difference of 1/32″ is rarely exceeded.

The usual methods of corrective adjustment are by means of lift fishplates joggled to various standard stock measurements and by the use of thin metal fishplate packings or shims. In some cases building up of the low rail by site welding is employed.

(11) *Is it the practice to ensure that rails rolled at the same time are laid abutting to give identical fishing angles and cross sections of rail at the joint?*

Answer. — See Table 2.

Although no information is given in the replies concerning any special measures taken to ensure the matching of depth and fishing angles of rail sections at joints, it appears that more attention is now being given to this point than in the past.

The Pennsylvania Railroad state that it is their normal practice for rails from the same rolling to be laid in at the same time whilst other administrations appear to favour this procedure where possible or convenient.

(12) *Do you take measures to avoid the rail end rolling out and forming a lip in the rail gap? What method is used?*

Answer. — See Table 3.

On the Pennsylvania Railroad the rail ends are chamfered and hardened. On the Victorian Railways the rail ends are chamfered and experiments are at present being undertaken in respect of hardening. In all other cases no special methods are adopted and the formation of lips is dealt with under maintenance.

(13) *Is any special arrangement utilised at the fishplate connection to support the rail, such as single or double saddles, special chairs, bridgeplates, bearing plates?*

Answer. — See Table 3.

The only special arrangement mentioned is a trial on the South African Railways of a rail joint bridge which it is stated, however, shows no marked improvement of the joint to justify the extra cost.

(14) *Describe the arrangements in use to allow expansion of the rails, diameter of the fishbolts, diameter of the holes in the rail and in the fishplates, distance between the holes, and as regards the rails, their distance from the end.*

Answer. — See table 3.

The arrangement employed to allow rail expansion is the use of holes in the rail of a larger diameter than that of the bolts passing through them, giving a total permitted movement of from 3/8″ to 9/16″.

(15) *State the rail gap allowed for expansion when laying the track in relation to the prevailing temperature. (See final section of questionnaire).*

Answer. — See Table 3 and Part C of Questionnaire.

(16) *Do you use wooden packings? How are they arranged? Are elastic fishplates utilised? Please supply particulars, drawings and commentary.*

Answer. — See Table 3.

Special wooden packings are not used at joints on any of the railways reported upon. Only the South African Railways refer to a special type of fishplate, the « Evertite » of United States origin, which they state has been found efficient but too costly for general use.

(17) *Give particulars of the fishbolts — diameter, length, number of threads per inch, shape of the head, shape and dimensions of the nut. What are the reasons for any distinctive feature adopted?*

Answer. — See table 3.

Fishbolts are mostly of 1″ or 1 1/8″ diameter, the number of threads per inch varying from seven to ten. The Pennsylvania Railroad has a specification providing for the use of alloy steel in their manufacture and uses a rolled thread as a standard.

The fishbolts vary in length between 4″ and 5 3/4″ according to the fishplates for which they are designed. There is no preference for square nuts as against hexagonal nuts. Bolts are usually prevented from turning by elliptical or pear-shaped necks except in one instance where the head engages with a rib on the fishplate itself.

(18) *Are arrangements in use to lock the fishbolts; for instance, lock nuts or spring washers? To what degree are they effective?*

Answer. — See Table 4.

The use of spring washers is standard practice on the Pennsylvania, Victorian and South African systems but in Great Britain fishbolts are not provided with any locking arrangements. On the South African Railways locknuts have also been used and are stated to have been effective.

(19) *Are the fishbolt nuts on the inside or the outside of the track? Why are they placed in the selected position?*

Answer. — See Table 4.

The outside position is generally preferred except in certain cases of electrified lines where the inside position is preferred as being more remote from the conductor rail. On the Pennsylvania Railroad and on the Victorian Railways the practice is to place the fishbolt nuts half inside and half outside in order to minimise the possibility of all bolts being broken by dragging equipment or derailment. On the South African Railways the practice is being introduced of placing the bolt nuts initially on the inside and changing them over to the outside and back again in successive years in connection with a regulation relating to the removal of fishplates for greasing and turning. A similar practice is current on some of the Indian Railways.

(20) *What is the method of manufacture of the fishplates? Are any special steels employed? Is any heat treatment adopted?*

Answer. — See Table 4.

The common method of manufacture is by rolling from steel bars cut to length, the holes being hot punched. A carbon content of from 0.30 to 0.42 % seems to be generally favoured, exceptions being on the Pennsylvania Railroad where the content varies from 0.35 to 0.60 %, and on the Victorian Railways where the content varies from 0.40 to 0.53 %. No heat treatment is adopted in Great Britain but oil-quenching is widely used elsewhere.

(21) *What are the specification requirements and the tests made before accepting fishplates and bolts, etc., from the manufacturer? Is there any requirement concerning the joint as a whole?*

Answer. — See Table 4.

No reply refers to any requirement concerning the joint as a whole.

(22) *Give particulars regarding the maintenance of fishplated joints?*

a) How often are they taken apart and lubricated?

b) What arrangements are made to take up wear — packings inserted at the fishing angles for example?

c) Are worn or damaged fishplates reconditioned for further use?

Answer. — See Table 4.

Question / Railway	12. Method of avoiding rail-lip in rail gap	13. Rail support arrangement at joints	14. Expansion provisions at rail joints		
			Total movement	Diam. holes in rail	Diam. bolts
British Railways	None	Not as a standard arrangement	0 — 1/2″	1.3/16″	1″
London Transport Executive	None	No supported joints in ordinary track	0 — 1/2″	1 1/8″	15/16″
Pennsylvania Railroad	Ends bevelled 1/16″ back and 1/8″ deep : ends hardened by rail makers	No special measures	0 — 3/8″	1.5/16″	1 1/8″
South African Railways	None	No special measures Rail joint bridges have been tried	0 — 9/16″	1 1/4″	1″
Government of India Railways	None	No special arrangements	0 — 9/16″	90 lbs. rail = 1 1/4″ 115 lbs. rail = 1 3/8″	1″ 1 1/8″
Nizam's State Railway	Maintenance attention	No special provisions	0 — 1/2″	1.3/16″	1″
Ceylon Government Railway	None	None	0 — 1/2″ 0 — 3/8″ 0 — 1/2″	90 lbs. rail = 1.3/16″ 88 lbs. rail = 1 1/8″ 80 lbs. rail = 1.1/16″	1″ 1″ 13/16″
Victorian Railways	Ends chamfered about 1/8″. Flame hardening of rail ends is being experimented with	No special arrangement	0 — 7/16″	60 lbs. = 1 1/8″ 94 lbs. & 107 lbs. = 1 1/4″	7/8″ 1″

Laying gap in relation to temperature F	16. Use of wooden packings and of elastic fishplates	17. Fishbolts				
		Diam.	Length	Threads per inch	Head	Nut
60′ rails : In open : below 50° = 3/8″ 50° — 75° = 1/4″ 75° — 100° = 1/8″ over 100° = nil	Not employed	1″	5 3/4″	10	Cup 5/8″ × 1 3/4″ Pear shaped neck	Square 1 5/8″ flats 1 1/8″ deep
60′ rails below 48° = 1/2″ 49° — 75° = 3/8″ 76° — 100° = 1/4″ over 100° = 1/8″	Not employed	15/16″	4 3/4″	9	Round 7/8″ × 1 3/4″ Pear shaped neck	Square 1 5/8″ flats 1 1/8″ deep
39′ rails : 26° — 50° = 1/4″ 51° — 75° = 3/16″ 76° — 100° = 1/8″ over 100° = nil	Not employed	1 1/8″ (cut thread) 1.1/16″ (rolled thread)	5 1/2″	7 (x 1 1/8″ dia.)	Ellipsoidal 45/64″ × 1 57/64″ Elliptical neck 1 1/2″ × dia.	Square 1.13/16″ flats 1/8″ deep
40′ rails : 25° — 44° = 5/16″ 45° — 64° = 1/4″ 65° — 84° = 3/16″ 85° — 104° = 1/8″	« Evertite » fishplates found very efficient in test installation	1″	5 1/2″	8	Round 7/8″ × 1 3/4″ Oval neck	Hexagonal
According to regional conditions. (See also Table 10)	Not employed	90 lbs. rail = 1″ 115 lbs. rail = 1 1/8″	5″ 5 1/4″	8 7	Square 7/8″ × 1.67″ 63/64″ × 1.86″	Hexagonal 1.67″ flats 1 5/16″ deep 1.86″ flats 1 7/16″ deep
Generally 1/4″ gap at prevailing temperatures	Not employed	1″	4 3/8″	—	Square 3/4″ × 1 5/8″	Hexagonal 1.63″ across flats 1″ deep
1/8″ to 3/16″	Not employed	1″ 1″ 13/16″	— 4″ 4.3/16″	— 8 —	— Round 13/16″ × 1 9/16″ Round 11/16″ × 1 3/8″	— Square 1 3/4″ flats 1″ deep Hexagonal 1″ deep
45′ rails : 40° — 65° = 1/4″ 65° — 90° = 3/16″ over 90° = 1/8″ up to 270′ rails 66° — 7/16″ 68° — 13/32″ 70° — 3/8″ 75° — 5/16″ 80° — 1/4″ 86° — 5/32″ 91° — 3/32″ 96° — nil	Not employed	60 lbs. 7/8″	4 1/4″	9	Cup 3/4″ × 1 5/8″ Elliptical neck 7/8″ × 1 1/8″	Hexagonal 1.48″ flats 7/8″ deep
		94 lbs. 1″ 107 lbs. 1″	Bar — 5 1/8″ Angle — 5 1/2″ 5 1/8″	8	Cup 3/4″ — 1 3/4″ Elliptical neck 1″ × 1 1/4″	Hexagonal 1.67″ flats 1″ deep

	18. Locking of fishbolt nuts	19. Fishbolt nuts inside or outside track	20. Fishplate manufacture and material
British Railways	Not standard practice.	Outside normally. On some electrified lines nuts are on inside — i. e. away from conductor rail side.	Class B steel (0.30 to 0.42 % c carbon) sawn or sheared to length Hot punched. No heat treatment
London Transport Executive.	Not used.	Inside the track for safety from positive rail.	Class B basic open hearth steel No heat treatment used.
Pennsylvania Railroad.	Spring washers are standard practice.	Half inside and half outside alternately.	Open hearth steel carbon 0.35 t 0.60 % holes punched hot. Quenched.
South African Railways.	Spring washers standard. « Evertite » lock-nuts are also used.	Formerly all outside but practice being introduced to change inside/outside in successive years when greasing fishplates.	Class B steel (0.30 to 0.42 % c carbon) sawn or sheared to lengt Hot punched. Oil quenched.
Government of India Railways.	Nuts have a special machined bearing surface. Some spring washers have been used effectively on ordinary nuts.	Generally outside track but on some lines two bolts of each fishplate, have nuts inside, which positions are interchanged every year.	Special steel, 36-42 tons ultima and minimum elongation 20 %. No heat treatment.
Nizam's State Railway.	Grovers spring washers are used with 85 lbs. rail.	Generally on inside.	The material is rail steel.
Ceylon Government Railway.	Not used.	Outside	No special treatment.
Victorian Railways.	Spring washers only are used and are found effective.	Half inside and half outside alternately.	Open hearth steel. Carbon 0.4 to 0.53 holes hot punched. Bot oil quenched and unquenche plates are used.

21. Fishplates and bolt specifications and tests	22. Maintenance of fishplated joints			23. Maintenance of rail level at joints
	(*a*) Taken apart and lubricated	(*b*) Methods of taking up wear	(*c*) Reconditioning of fishplates	
lates : e breaking strength 36-42 tons sq.″ 0 % elongation. Bend test between oles to 120° without sign of fracture. olts similar.	Annually in early spring.	Steel shims on upper fishing surface or reconditioned or new plates.	Forged under drop hammer to give rather deeper section than when new.	(See 22*b*) Particular attention is paid to packing of joint sleepers.
lates : e breaking strength 36-42 tons sq.″ 0 % elongation. Bend test between oles to 120° without sign of fracture. olts similar.	Taken apart and lubricated every second year.	Parallel or tapered shims.	No reconditioning of fishplates.	Joint maintained by packing of sleepers in day-to-day maintenance.
lates : 35 tons sq.″ Tensile 50 tons sq.″. Bend ut cracking to 90° round dia. 3 times ness of specimen. Elongation 12 %. are carbon open hearth or alloy steel ower than 0.35 % carbon. Yield 40	Anti - corrosion grease when rail is laid or fishplates are renewed.	Oversize fishplates 1/32″, 1/16″, 3/32″.	Processed and reformed to original or oversize.	Dishing is rectified by welding.
lates : le breaking strength 36-42 tons and , elongation. Bend test between bolt to 120° without sign of fracture. olts similar.	Annually on the more important lines.	Enlarged fishplates. Limited use of shims.	Pressed out to oversize.	With the tailed fishplate dishing is disappearing. Battered rail ends built up by welding.
tests for fishplates.	Annually.	Shims or oversize fishplates.	Yes.	Special attention to packing of joint sleepers. Crippled rails are cropped or de-hogged.
—	Annually.	Shims were used experimentally but not adopted.	No.	Hogged rails are renewed.
—	Annually.	Packings inserted.	No.	—
plates : quenched) Minimum elongation = 15%. o 48 tons ultimate tensile strength. ile test. Fishplates : (Quenched) Mini- n elongation = 10 %. 44 tons ultimate le strength. 90° bend test and tensile bolts : (Unquenched) Minimum elonga- = 20 %. 35 tons ultimate tensile ngth. Tensile and bend tests. Fishbolts nched. Minimum elongation 12 %. mate 44 tons. Tensile and bend tests.	Only when «frozen » or rusted to the rail.	Worn fishplates are reconditioned by being hot pressed and given a camber.	All serviceable worn fishplates are reconditioned as in previous column. (Question 22*b*).	Fitting of reconditioned fishplates, beater or measured packing, tightening bolts and renewing washers are usual methods.

a) On most railways normal maintenance activities provide for the taking apart and lubrication of fishplates on an annual basis. The Pennsylvania Railroad however applies anti-corrosion grease only when the fishplate is assembled or removed and there is no set schedule for periodical removal. The Victorian Railways only take apart and lubricate fishplates as necessary. The London Transport Executive deal with removal and lubrication on a biennial basis.

b) Wear on the fishing angles of the fishplate and rail is taken up in general by the insertion of sheet metal packings, which are sometimes tapered in form, and by the use of oversize fishplates.

c) The reconditioning of worn fishplates by reforging and for obtaining oversize fishplates is common practice.

(23) *What measures are taken in the maintenance of the joint itself, for instance, to rectify low rail level (dishing) at the joint? How often is this done?*

Answer. — See Table 4.

Conservation of joints is regarded as a matter of routine maintenance particularly in respect of careful attention being given to the condition of the fishplate, tightness of bolts and fastenings and to the adequate packing of joint sleepers.

No administration appears to be seriously troubled by rail dishing at joints but in those cases where dishing is experienced the wear is generally made good by welding.

(24) *Have you found differences in the maintenance of the level of the track at the joint position associated with the type of fishplate joint used? Is there a difference according to whether the joints are opposite each other or staggered in position?*

Answer. — See Table 5.

Although most of the replies infer that the type of fishplate joint used has some influence on the maintenance of the level of the track no comparative analysis has been supplied. It is stated that with heavy section rail close sleepered joints have been found to stand proud in relation to general rail levels.

No comparison between the maintenance of joints when opposite each other and when staggered is available beyond a statement by the Government of India Railways that the difference is small.

(25) *Give a general indication of experience with the various types of fishplates in use, for example, the percentage of breakages, difficulty in maintaining level, etc.*

Answer. — See Table 5.

The incidence of breakages of fishplates of whatever type in use is negligible and there is no particular difficulty in maintaining the level of the track.

(26) *Give drawings and particulars of the type of insulated joints used for track circuit signalling purposes.*

Answer. — See Table 5.

The types of joint for track signalling purposes practically all take the well known simple form of suitably shaped fishplates with bolt and fishplate insulation liners and insulating end fibre posts. The use of insulating fishplates of impregnated laminated wood however seems to be gaining ground for this purpose. A type of insulated joint largely in use by British Railways consists of drop forgings and fibre insulations, as illustrated in Figure 7. End posts are mostly of 1/4″ thickness but London Transport and the Victorian Railways use end posts 3/8″ thick.

***

SUMMARY.

a) Where railways have in recent years adopted heavy running rail as standard the design of the rail profile has evidently been greatly influenced by study of its

TABLE 5.

	24. Difference in joint maintenance according to type of joint or according to whether opposite or staggered	25. Experience with different types of fishplates. % of breakages. Difficulty in maintaining level	26. Insulated joints used for track signalling purposes
British Railways.	Joints opposite. Close sleepered joints with 113 lbs. rail having very stiff joints were often high relative to the intermediate sleepers.	The change to flat bottom rail is too recent to establish data on the improvements in joints.	Main types are (*a*) drop forged with fibre insulation and (*b*) laminated wood impregnated with synthetic resin.
London Transport	Joints with 4 hole fishplates require less maintenance than joints with 2 hole fishplates.	Fewer breakages with tailed plate than with symmetrical plates. Less wear on fishing angle with 4 hole plates than with 2 hole plates.	Two types — one has fishplates of reduced depth and fibre inserts, 1/8″ thick, with end post 3/8″ thick, the other is a wooden laminated plate, mainly used in tube tunnels, but a number are installed elsewhere.
Pennsylvania Railroad	Normal practice to stagger joints in U. S. A. so no comparison with joints « opposite » is available.	Little difference found in various tests. Breakage of standard joint is negligible. Proper maintenance is essential to avoid excessive wear.	Special 6 hole fishplates 3′ 2 1/2″ long extending around base of rail with shaped fibre inserts 3/16″ thick under head and 1/8″ thick around base, and 1/4″ end posts.
South African Railways	Comparative tests are still being carried out on opposite and staggered joints.	Breakages are rare. The more rigid the joint the easier is maintenance until wheel batter sets up.	Heavy fishplates, 2″ × 3.25/32″ × 18″ with 4 bolts. 1/8″ shaped fibes with 3/16″ end post. Tests satisfactory to date of design with lighter fishplate.
Government of India Railways	Type of fishplate affects maintenance. Differences in maintenance of staggered or opposite joints is small.	Breakages uncommon. Old type of fishplate joint required more maintenance.	Special fishplates with shaped fibre inserts 1/8″ thick. End post 1/4″ thick.
Nizam's State Railway	No differences.	Failures rare — no particular difficulty in maintaining joint level.	Special fishplates with shaped fibre inserts, minimum thickness 1/16″ and with end posts 1/4″ thick.
Ceylon Government Railway	No differences.	No particular information, only standard types used.	Insulating packings — wooden laminated fishplates under trial.
Victorian Railways	No differences.	Insignificant percentage of breakages. No particular difficulty in maintaining level.	Flat bar section fishplates with fibre liners, ferrules and washers. End post 3/8″ thick. Fishbolts of 1″ dia. high tensile steel.

accommodation of a suitable profile of fishplates.

It can be deduced that the modern tendency is to give close attention to the strength and stiffness of the fishplates, particularly with suspended joints, but at the same time to adhere to traditional principle in design. Numerous types of special joint have received consideration from time to time but these usually involve complicated constructions which have failed to find lasting favour.

maintaining the two rails reasonably level with one another at joints. Further, serious dishing at joints seems to be decreasing with modern design and maintenance standards.

e) Spring washers as a locking device on fishbolt nuts are widely used but the use of self-locking nuts is rare. No device of this kind is adopted however for normal use by British Railways who achieve a similar result by the use of fine threaded fishbolts, viz. 10 threads per inch as against the more usual 8 threads per inch

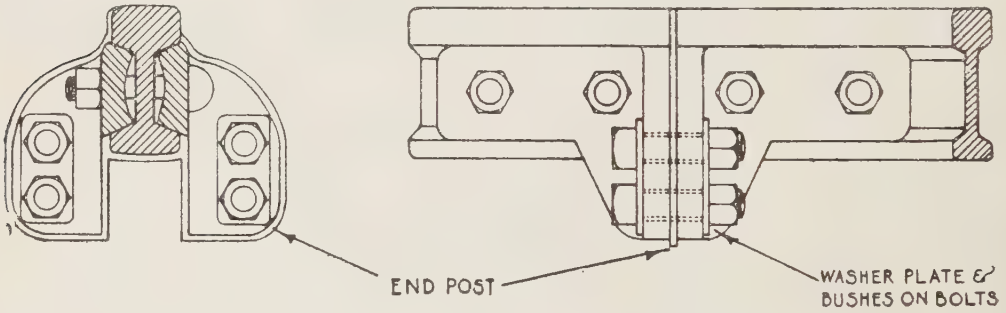


Fig. 7. — *British Railways.*
Williams Insulated Blockjoint.

b) Staggered joints are the general practice in the United States but elsewhere joints opposite one another are preferred. The advantages and/or disadvantages of the alternative arrangements remain undetermined, and it seems reasonable to assume that there is no outstanding technical difference between the two methods.

c) One of the most important aspects of the variation in fishplate cross section is the slope of the fishing angles. Some administrations favour equal angles top and bottom whilst others prefer a flatter angle at the bottom than at the top, but it is noted in all the latter cases that width of bearing surface is greater at the bottom than at the top. All administrations favour a fairly steep inclination of from 14° to 20° at the top.

d) It does not appear from the replies that serious difficulty is encountered in

for a 1″ dia. bolt or 7 threads per inch for 1 1/8″ bolts used elsewhere.

f) It is quite common practice for the fishbolt nuts to be disposed half outside and half inside the track, but the preferred position is outside the track.

g) Fishplates are mostly manufactured from steel with carbon content up to 0.42 % and tensile strength of up to 42 tons per square inch, but in America and Australia the use of steel with a higher carbon content is standard. No novel feature of the testing of material is revealed in the replies and it seems reasonable to deduce that the materials used and the methods of testing them are satisfactory, as breakages of fishplates are rare.

h) A wide use is indicated of thin steel packings, often tapered, for worn fishing angles and this method is considered to present some advantage for local wear

of fishplate and rail as compared with oversize fishplates. The use of the latter remains the general remedy for overall wear of fishing angles.

j) Insulated joints for track signalling purposes are unquestionably a source of mechanical weakness unwelcome to the engineers responsible for the track maintenance. The replies however do not indicate any novel types and the problem remains of producing a joint which, while being satisfactory electrically, will at the same time afford mechanical strength and stiffness akin to the normal fishplated joint.

The replies give no evidence of recent major changes in the broad principles of design of the fishplated joint. Such improvements as have been adopted have taken the form of evolutionary development of traditional designs rather than of radical innovation.

(B). — **Use of long welded rails : Optimum length in relation to the safety and good condition of the permanent way.**

1. *What is the normal rail length as obtained from the rolling mills? Give the profile and state the weight per unit length.*

Answer. — See Table 6.

2. *What is the length of long welded rail used in normal practice in running tracks carrying trains at high speeds and with heavy axle loads? What determines this length? Supply dimensioned cross-sectional drawing and particulars of the weight per unit length if different from that shown under 1.*

Answer. — See Table 6.

It is a common practice for rails normally to be welded into lengths varying from 120

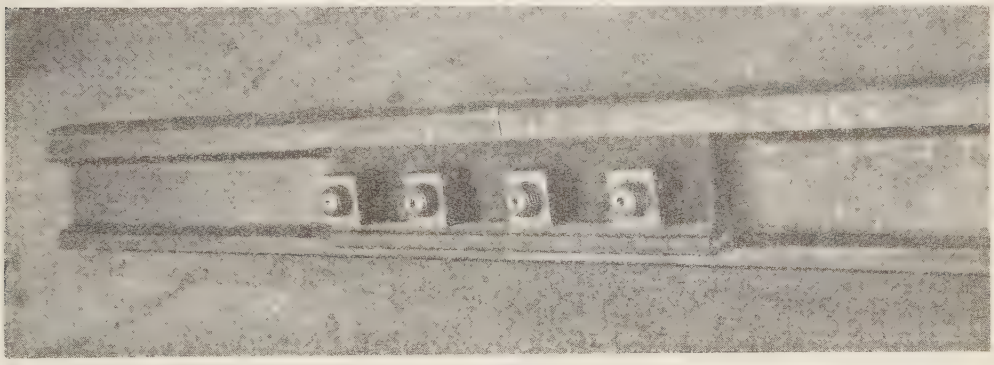


Fig. 8.

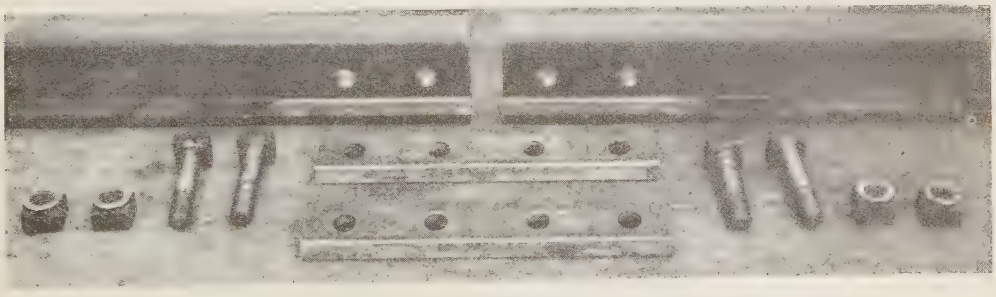


Fig. 9.

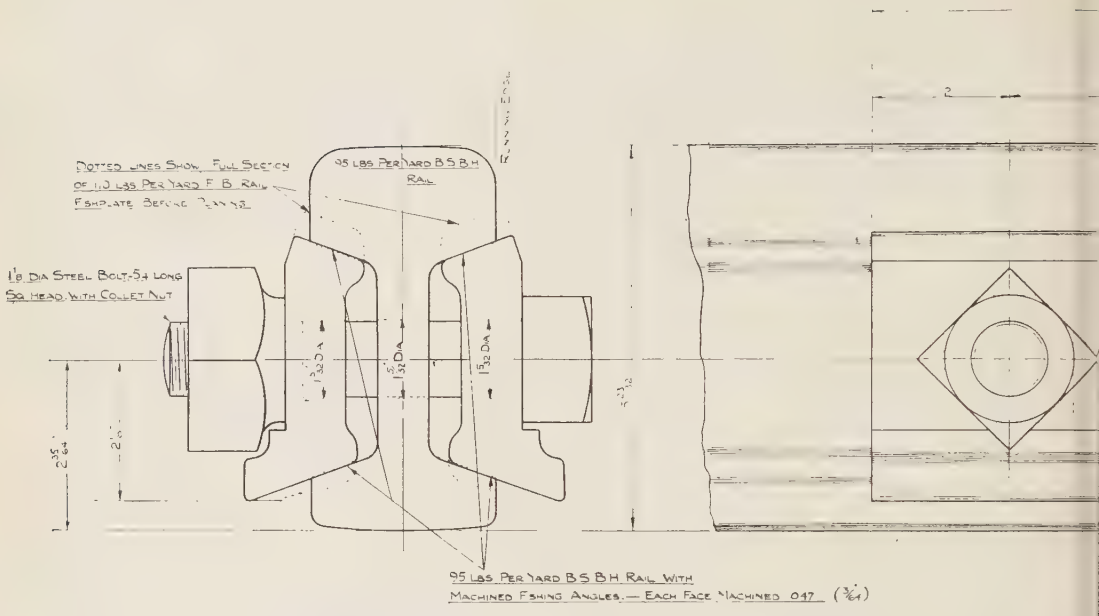
TAI

(B) **Use of long welded rails : Optimum length in relatio**

Question	1. Normal rails			2. Long welded rails — Normal practice		
Railway	Length	Profile	Weight per yard, lbs.	Usual length	Determining factor	Cross secti and weigh
British Railways	60′ 60′	Bull-head Flat bottom	85 lbs. 95 lbs. 113 lbs. 109 lbs. 98 lbs.	120′ 180′	Convenient handling and maintenance	Bull head 95 lbs.
London Transport Executive	60′	Bull-head	95 lbs.	300′	Welding facilities and transport	95 lbs.
South African Railways	40′	Flat bottom	96 lbs.	120′	Transport	F. B. 96 l
Government of India Railways	42′ (Broad gauge) 39′ (Metre gauge)	Flat bottom	50 lbs. 60 lbs. 75 lbs. 90 lbs. 115 lbs.	210′	—	—
Victorian Railways	45′	Flat bottom	94 and 107 lbs.	270′	Welding plant at depot	94 lbs an 107 lbs

ety and good condition of the permanent way.

3. Maximum length of welded rail					4. Rail fastenings	5. Anti-creep devices		
Main lines	Stations	Bridges and viaducts	Tunnels			Type	Number	Position
			Rail length	Transition provisions at ends				
120′ 180′	120′	180′ to 429′	180′ 315′	None None	Bull-head rails keyed in cast-iron chairs secured to sleepers by screws or bolts. Flat bottom rails on cast-iron or steel baseplates with spring spike fastenings.	Not normally required		
300′	300′	300′	300′	Expansion switches	Rails with wood or steel keys in cast-iron chairs secured to wooden sleepers by screws.	«Phillips»	Up to 6 per 60′ rail	
120′	120′	120′	3183′	None	Rail secured by steel taper key to cast-iron chair which is attached to sleeper by coach screws. With steel sleepers clips and tee bolts are used.	Not required		
216′	216′	315′	—	—	Bearing plates and dog spikes.	Not required		
270′	270′	270′	Through tunnels	None	Bearing plates and dog spikes.	« Fair »	According to requirements	Ends and middle


DOTTED LINES SHOW FULL SECTION OF 110 LBS PER YARD F B RAIL FISHPLATE BEFORE DRILLING
95 LBS PER YARD B S B H RAIL
1⅛ DIA STEEL BOLT-5¼ LONG SQ. HEAD WITH COLLET NUT
95 LBS PER YARD B S B H RAIL WITH MACHINED FISHING ANGLES.— EACH FACE MACHINED 047 (¾)
END ELEVATION

feet to 300 feet, the selection of the length adopted being mainly determined by accommodation at the welding plant and by transport facilities. Rails of standard profile, analysis, and weight, are used for both welded and unwelded tracks.

3. *What is the maximum length of welded rail of the type indicated in question 2 laid in the track? Give the particulars in relation to :*
   a) Main line track;
   b) Main line tracks in stations and sidings;
   c) Steel bridges and viaducts;
   d) Tunnels.

   In regard to (d) indicate the lengths of rail installed at or near to the tunnel mouth to resume gradually the normal length of rail employed in the open.

Answer. — See Table 6.

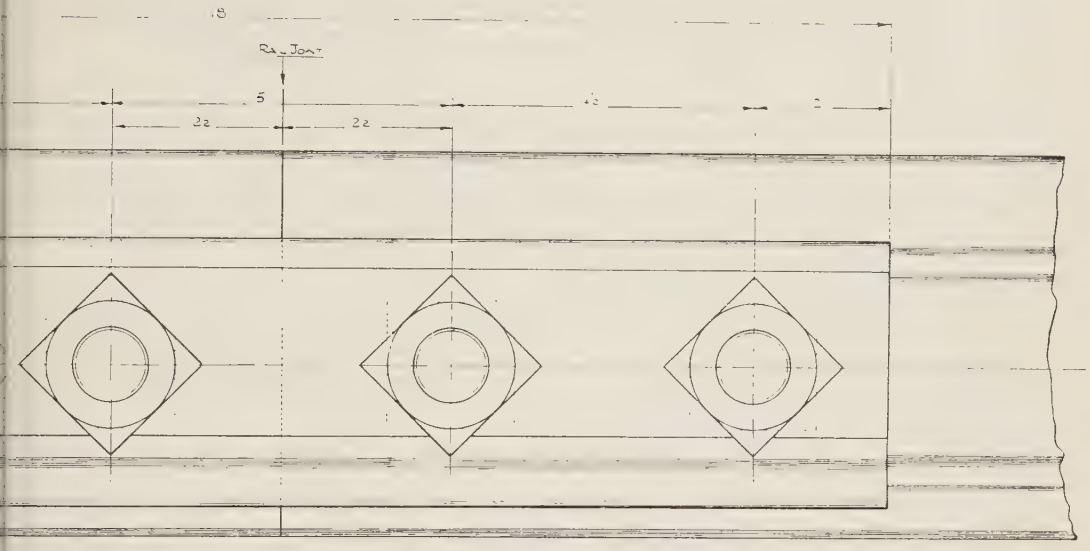
a) and *b*) Open tracks, 120, 180, 216, 270 and 300 feet.

c) Bridges and Viaducts. Generally as (*a*) and (*b*) but two instances are quoted of maxima of 315 ft. and 429 ft.

d) Tunnels. Generally as (*a*) and (*b*), The practice on the South African Railways however, is for their normal 120 ft. welded lengths to be additionally site welded from portal to portal. In this connection a maximum length of 3183 feet is quoted. The Victorian Railways have also installed continously welded rails through some tunnels.

No provision is made on any system at or near the tunnel mouths to effect a gradual transition to open track conditions.

In the case of London Transport the normal 300 feet welded rails are joined rigidly together as described later under Question 8 into continuous lengths of half a mile on open tracks, and up to 3 1/2 miles in tunnel.



Side Elevation

4. *Give particulars of the rail fastenings to the sleeper, soleplate, chair, etc.*

Answer. — See Table 6.

The rail fastenings employed on long welded lengths conform to those in general use on normal unwelded sections of both bull-head and flat bottom rail. They include clips, screws, dog spikes, steel taper keys and elastic spikes in the case of flat bottom rail, and steel or wooden keys in the case of bull-head rail.

5. *Are rail anti-creep devices employed? If so, what is the type, number, and position per rail length?*

Answer. — See Table 6.

Generally no, as being considered unnecessary. Exceptions are :

(i) the use by Victorian Railways of anchors at the centre, and at each end, of the welded tracks;

(ii) the use by London Transport of rail anchors distributed throughout the length as found necessary.

6. *Give particulars of the sleeper spacing in running tracks at the welds and at the rail joints. Is the density of sleeper spacing related to the length of the rail?*

Answer. — See Table 7.

In lengths welded by the flash-butt process no variation in normal sleeper spacing is made at the weld. On the Government of India Railways the sleeper spacing at Thermit joints is the same as that at fishplated joints.

7. *What kind of ballast is use in the various tracks?*

Answer. — See Table 7

8. *What joint arrangements are adopted at the rail ends — normal or special fishplates or special expansion joints? Give a description, particularly as regards bridges and viaducts. Supply photographs and drawings.*

Answer. See Table 7.

In most cases the ordinary fishplated joint is employed at the ends of long welded lengths. London Transport however, adopt the practice of joining several 300 feet welded lengths together by means of a specially designed accurately fitting butt joint. (See Figures 8, 9 and 10).

Rails after being carefully checked for squareness at the end are lightly milled at the fishing angles over the length covered by the fishplate. The fishplates themselves are manufactured from one of the heavier fishplate bar sections machined to fine limits, to ensure a close fitting assembly with the rails. Four 1 1/8″ dia. bright fishbolts are employed in 1-5/32″ dia. holes drilled in both fishplate and rail, and expansion and contraction movement at the joint is practically eliminated. The 1/2 mile lengths of welded rail assembled in the open, and the still longer lengths in the tunnel, may thus be regarded as continuous lengths of rail. The 1/2 mile lengths terminate in a switch and stockrail arrangment, (See Figures 11 and 12) which permits control of seasonal stresses in the rail.

9. *Is any special provision made to anchor the track to the formation; if so, give description.*

Answer. — See Table 7.

No reference is made to any special provision of this kind as current practice. South African Railways refer, however, to one past experiment in which scrap rails were fastened to the underside of the sleepers, but it is understood that the results obtained were indeterminate.

10. *What are the temperatures at which welded track is laid and what are the seasonal and daily temperature ranges to which it is exposed? What are the regulations adopted in regard to installing welded rails at the locations referred to in Question 3?*

Answer. — See Table 8.

There are no special regulations which define temperatures at which rail laying shall take place, but it is generally agreed that it is desirable to avoid laying rails when extremes of temperature prevail.

11. *Are long welded rails in open track adjusted seasonally to modify expansion or contraction stresses? Is any method in use for examination or testing of welds in service in the track?*

Answer. — See Table 8.

Only on the Victorian Railways and on London Transport is open track adjusted seasonally as a regular practice. In the case of the Victorian Railways no details are given. In the case of London Transport welded rails stress release is effected during the first spring and first autumn seasons following initial installation, and subsequently in the spring of each year. The ordinary rail keys are removed from the chairs over a 1/2 mile length of single rail at a time, and special long loosely fitting timber keys inserted at intervals of every tenth sleeper to allow free movement of the rail at the special switches provided at the end of each 1/2 mile length. The operation takes place under traffic conditions and generally when the temperature is near the middle of the seasonal range.

On British Railways adjustment is made only if creep has taken place due to traffic or thermal conditions and generally follows practice as for unwelded rails.

Inspection of welds in the track appears to be by routine visual examination.

12. *Has abnormal rail creep been noticed in the track with long welded rails?*

Answer. — No. — See Table 8.

TABLE 7.

Question	6. Sleeper spacing in running tracks				7. Kind of ballast	8. Joints at ends of lengths	9. Anchorage of track to formation
Railway	Normal	At welds	At rail joints	Relation to rail length			
British Railways	2′—6 1/2″	2′—6 1/2″	2′– 0″	Only minor variations.	Crushed limestone or crushed granite or crushe dslag, size 3/4″—2″.	Mostly normal but in some cases 1/8″ wider expansion gap	None
London Transport Executive	2′—7″	2′—7″	2′—2″	None.	Carboniferous limestone crushed 3/4″ to 1 1/2″.	Ends of rails milled and machined fishplates fitted without provision for movement.	None
South African Railways	Wood sleepers : 2′—3″ Steel sleepers : 2′—3″	2′—3′ 2′—3″	1′—8″ 1′—6″	Normally 2376 sleepers per mile. Experiment with 2772 sleepers per mile on 960′ rails.	Crushed stone.	Normal tailed 4 hole fishplates.	None
Government of India Railways	—	Flash butt = normal. Others as joints	1′—7″		Stone.	Ordinary standard.	None
Victorian Railways	2′—3 1/2″	Flash butt = normal. Thermit 2′—2″	1′– 6″	None.	Crushed rock of 1 1/2″ gauge on main lines. Crushed gravel of 1 1/2″ gauge on secondary and branch lines	Ordinary standard	None

TABLE 8.

Question	10. Temperature when laying			11. Seasonal relief of stresses and track tests	12. Abnormal creep effects	Buckling of track — transverse or vertical
Railway	Normal for long rails	Daily range	Seasonal range			
British Railways	Usually between 40°F and 65°F	Up to 60°F	Approx. 100°F	Only if creep has taken place. Welds are now subject only to routine visual inspection.	None	None
London Transport Executive	Prevailing temperature, avoiding extremes	60°F	100°F	Long welded lengths released during first spring and first autumn after laying, subsequently only in spring. Welds visually inspected, with aid of mirrors.	None	Some transverse but no vertical buckling.
South African Railways	No restrictions specified	About 80°F	About 115°F	No seasonal adjustment. No service testing of welds in track.	None	None
Government of India Railways	Minimum 47°F to 73°F Maximum 108°F to 126°F	About 15°F	68°F to 91°F according to location	No seasonal adjustment. Only visual examination of welds.	None (Test gave .35" per annum)	None
Victorian Railways	Have been laid between 66°F and 96°F	—	100°F	Seasonal adjustment is effected. Only visual examination of welds; no special test.	None	Transverse buckles have occured where ballast is light.

13. *Has transverse or vertical buckling of the track been encountered?*

Answer. — See Table 8.

Experience indicates that the incidence of track buckling is no greater with long welded rails than with unwelded rails.

please give a full description with drawings, photographs and calculations.

Answer. — See Table 9.

Yes, although full particulars of the actual experiments undertaken are available only in respect of British Railways and

Fig. 11.

14. *Has experimental work been done to evaluate the stresses in the rail, also the resistance of the rail fastenings and of the sleepers, to the movements of long welded rails? If so,*

London Transport. Detailed results of these tests are presented in Railway Papers Nos. 3 and 4, and 27, of the Institution of Civil Engineers under dates

TABLE 9.

Question / Railway	14. Evaluation of stresses; resistance and movements	15. Experimental installations of specially long welded lengths	16. Conclusions and intentions as to normal use of very long welded lengths
British Railways	See Inst. Civil Engineers Railway Division Papers Nos. 3 and 4, October, 1942 by Messrs. Loach and Campion « Experiments with a Long Welded Length of Bull-head Railway Track ».	A length of 1914 ft. of track was laid in main line track with 95 lbs. rails 300′ long. Expansion gaps were as for normal 60 ft. rails.	180 ft. lengths are practical and advantageous.
London Transport Executive	See Inst. Civil Engineers Railway Division Paper, No. 27, January, 1948 by Messrs. Dunton and Brinsmead « Design, Installation and Maintenance of Long Welded Rails ».	None.	Track work is reduced, enabling a better standard of maintenance with the same labour force. Noise is reduced, particularly in tunnels, where long welded rails will be extensively used. Length in open is undecided.
South African Railways	Experimental work on rail stresses has been done and the results are under analysis. New apparatus has now been obtained which should allow holding power of sleepers also to be derived.	480′, 960′ and one mile lengths built up from 120′, welded rails jointed on site by thermit or Secheron process.	Results very encouraging but conclusions await progress of experiments. Benefits appear to warrant adoption on large scale.
Government of India Railways	Research being put in hand.	Experiments with 420′ lengths to be made in the immediate future.	216′ length found fairly satisfactory so far. Very long lengths are not at present proposed pending research.
Victorian Railways	No experimental work has been done to evaluate stresses.	A length of 4748 ft., 94 lbs. A. S. rails, with fusion welds has been installed on « S » curves of very flat radius.	270′ maximum lengths adopted as standard practice, as confining temperature stresses within reasonable limits for economical ballast sections. Policy under review.

October 1942 and January 1948 respectively.

In the case of British Railways the experiment took the form of measurement in the field of absolute and comparative expansion movements of both free and restrained rails. In the case of London Transport the experiment took the form of establishing the resistance presented by sleepers and fastenings to longitudinal track movement, and certain tests were also made in respect of resistance to lateral distortion of the track.

In both these cases the following equation was used to relate the stress in completely restrained rail to ranges of temperature.

Stress $= qET$.

Where E = Young's modulus of elasticity.

T = temperature range in degrees F,

q = linear coefficient of expansion of steel rails per degree F.

From the experiments referred to it is concluded that a range of rail temperature of 120°F would produce a corresponding stress-range of about 10.6 tons per square inch, equivalent to 98.5 tons on a 95 lbs. bull-head rail section, or of 200 lbs. per square inch for every 1°F rise or fall in temperature.

The South African Railways state that in tests with 480 ft. rails, stress was developed at the rate of 162.5 lbs. per square inch per 1°F change of temperature, and that American experiments made on still longer rails assess it at the somewhat higher value of from 180 to 190 lbs. per square inch per 1°F rise.

On one of the regions of British Railways an experimental length showed no distortion under a compressive stress of 51.8 tons per rail, or 6.6 tons per square inch.

The above stresses are of course exclusive of those imposed by rolling stock.

The following table, gives the results of tests carried out by London Transport to determine the resistance to movement of rail fastenings:

TYPE OF KEY	Resistance to rail movement per chair or baseplate : tons			
	1st thrust	2nd thrust	3rd thrust	4th thrust
95-lb. B.H. rail, new oak keys driven in direction of thrust	1.48	1.56	1.56	1.56
95-lb. B.H. rail, new oak keys driven against direction of thrust	1.15	1.15	1.15	1.15
95-lb. B.H. rail, used oak keys driven in direction of thrust	1.32	1.32	1.28	1.28
95-lb. B.H. rail, used oak keys driven against direction of thrust	1.24	1.24	1.24	1.24
95-lb. rail, new steel keys driven in direction of thrust	2.39	2.39	2.39	2.39
95-lb. rail, new steel keys driven against direction of thrust	2.39	2.06	1.94	1.86
95-lb. rail, used steel keys about 5 years old and 12 times redriven. Driven in direction of thrust.	1.99	1.99	2.11	2.33
95-lb. rail, used steel keys about 5 years old and 12 times redriven. Driven against direction of thrust	1.85	1.77	1.64	1.56
95-lb. rail, new Jarrah keys driven in direction of thrust	2.5	2.5	2.33	2.33
95-lb. rail, new Jarrah keys driven against direction of thrust	2.5	2.5	2.4	2.2
90-lb. F.B. rail, elastic spike fastenings (new)	0.93	0.96	0.96	0.96
90-lb. F.B. rail, clip type fastenings (new)	1.03	1.03	1.03	1.03

Fig. 13.

The resistance of sleepers to longitudinal movement of the track has also been the subject of experiments by British Railways and London Transport. The following table, gives results of these tests :

CONDITIONS OF BALLAST	Test by	Sleepers	Resistance per sleeper to Longitudinal movement: tons	
			With Current Rails	Without Current Rails
			Slag Ballast	
Track resting on ballast : no boxing . . .	LT	8′-6″ × 10″ × 5″	0.246	0.165
Beds filled to ½ depth of sleeper : no shoulder ballast	LT	»	0.37	0.37
Beds filled to sleeper level : no shoulder ballast	LT	»	0.585	0.534
Beds filled to sleeper level with 12″ wide shoulder ballast	LT	»	0.638	0.576
			Limestone Ballast	
Track resting on ballast : no boxing . . .	LT	»	0.165	0.144
Beds filled to ½ depth of sleeper : no shoulder ballast	LT	»	0.411	0.288
Beds filled to sleeper level : no shoulder ballast	LT	»	0.617	0.576
Beds filled to sleeper level with 12″ wide shoulder ballast	LT	»	0.823	0.66
Beds filled to 4 ½″ depth with 18″ wide shoulder ballast	BR	9′ × 10″ × 5″	—	0.45
Beds filled to 1 ½″-3″ above sleeper level and on 2 feet wide shoulder ballast and on 6 foot	BR	8′-6′ × 10″ × 5″	–	0.988

Fig. 14.

15. *Have you experimented with specially long welded rails in main line tracks in addition to the normal long length already described? Give the number and particulars of these tests. Describe any special arrangements used, particularly at the rail ends. What results were obtained? Was special maintenance needed? What particular precautions were necessary for laying, inspection and routine attention on these test lengths?*

Answer. — See Table 9.

British Railways refer to a test length of 1914 feet of track laid with 300 ft. welded rails joined by the « Ellson » type joint providing normal expansion gaps as for 60 feet rails. In 1948 the track showed some instability, which, though it was not repeated in 1949, did necessitate in that year careful observation of the section and special attention to unkeying and re-keying of the rails in hot weather to equalise the compression.

South African Railways report that in 1945 twelve lengths each of 480 feet, formed by welding on site by the Thermit process four 120 ft. flash butt welded rails, were installed with normal joints as for 60 feet rails. In 1948 two further lengths were added, one of 480 ft. rails and one of 960 ft. rails, the latter length being laid on steel sleepers. These additional long rails were laid during mild weather conditions at

temperatures rather higher than intended, namely 76 — 88°F. The joints were staggered by an amount of 6'11 3/4" and expansion gaps provided of 1/8" and of about 3/16", at the ends of the 480 ft. rails and of the 960 ft. rails respectively. It was subsequently found that the rail ends contracted by amounts up to the maximum joint gaps of 3/4" even at a temperature as high as 68°F. The view is taken that the adoption of tight joints when laying at the mean annual temperature would prevent the joints in long rails opening to such an undesirable extent. No special difficulty in maintenance is reported with these rails.

Victorian Railways report the laying in 1937 of 4 748 ft. 94 lbs. rails, fusion welds, on «S» curves of very flat radius. No special arrangements have been used, except that the track is heavily ballasted. A gradual lateral movement not exceding 3" takes place in hot weather. The results generally have been satisfactory and no special maintenance has been needed but an additional patrol of track is arranged in times of hot weather.

16. *What conclusions have you reached, and what are your intentions regarding the normal use of very long welded rails in main line tracks with heavy traffic? What, in a general sense, are your long term views on the use of very long welded rails?*

Answer. — See Table 9.

All administrations appear to regard their standard lengths of welded rail as being suited to more extensive installation. British Railways feel that further practical experience with the new 109 lbs. section flat bottom rail is necessary before future policy on installing welded rails can be formulated.

London Transport propose to continue with 300 ft. welded rails tight-jointed into half mile sections, and have in contemplation experiments in locking up the stresses in the half mile sections by means of screw clamps applied to the expansion switches at a rail temperature of about 75°F.

South African Railways state that the benefits to be derived from long rails are considered to be such as to warrant their adoption on a large scale where conditions are suitable. As a result of the experiments now being made it may be expected that there will be considerable development of long welded track in South Africa.

Victorian Railways state that the 270' maximum lengths of welded rail have been adopted as standard practice at present. The major reasons for this policy are, convenience for welding at the depot, maintenance replacement and confining temperature stresses within reasonable limits for economical ballast sections. The whole question of the design and laying of welded track is under review.

It is a general view that the elimination of joints by welding promotes good riding and reduces maintenance, but no administration attempts to quantify these improvements or place an economic value upon them.

***

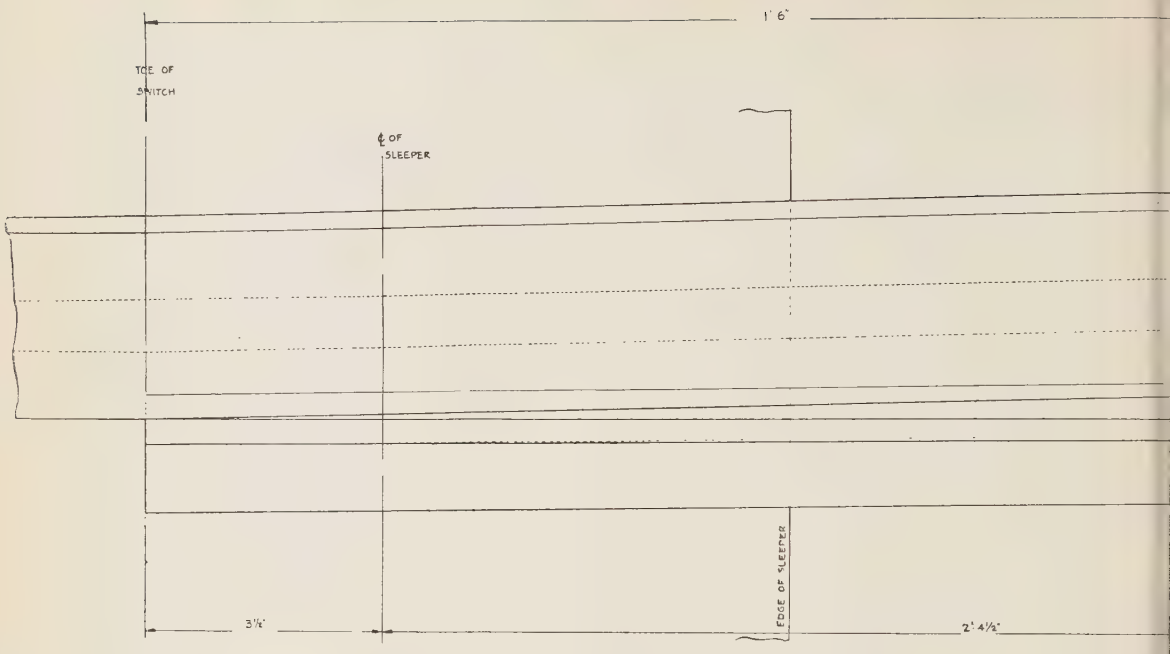
SUMMARY.

All administrations replying to the questionnaire appear to prefer the flashbutt process to other processes of effecting rail welds. British Railways and London Transport are not disposed to use site welding, but other railway systems use site welding to joint up standard flashbutt welded lengths as necessary. The ultimate economic length of continuously welded rail does not appear as yet to have been determined.

(*k*) The rails welded are in every case of the same specification as those used for normal installations.

(*l*) Although lengths between 120 feet and 300 feet are commonly adopted as the ex-depot length for general installation, there is a tendency to use longer lengths with site welding in cuttings and on viaducts where exceptional lateral rigidity of the track is practicable, on bridges for the elimination of the impact of joints on the span, and in normal tunnels where no limit of length apparently needs to be prescribed.

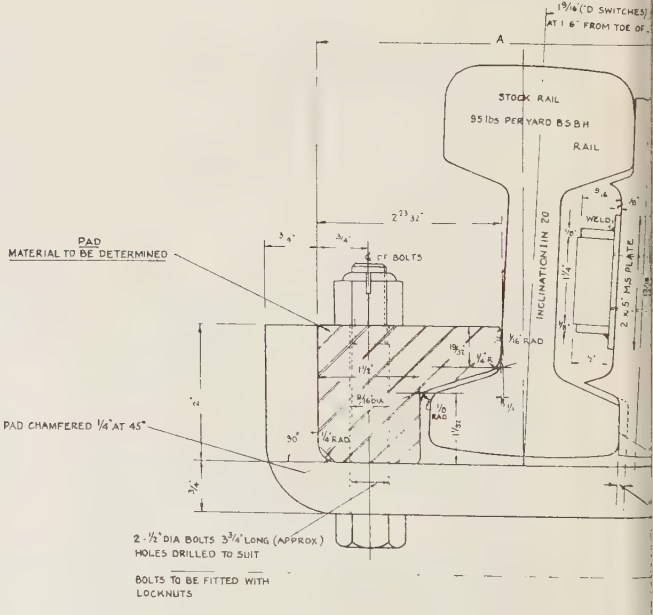
(*m*) No special type of rail fastening



PLAN

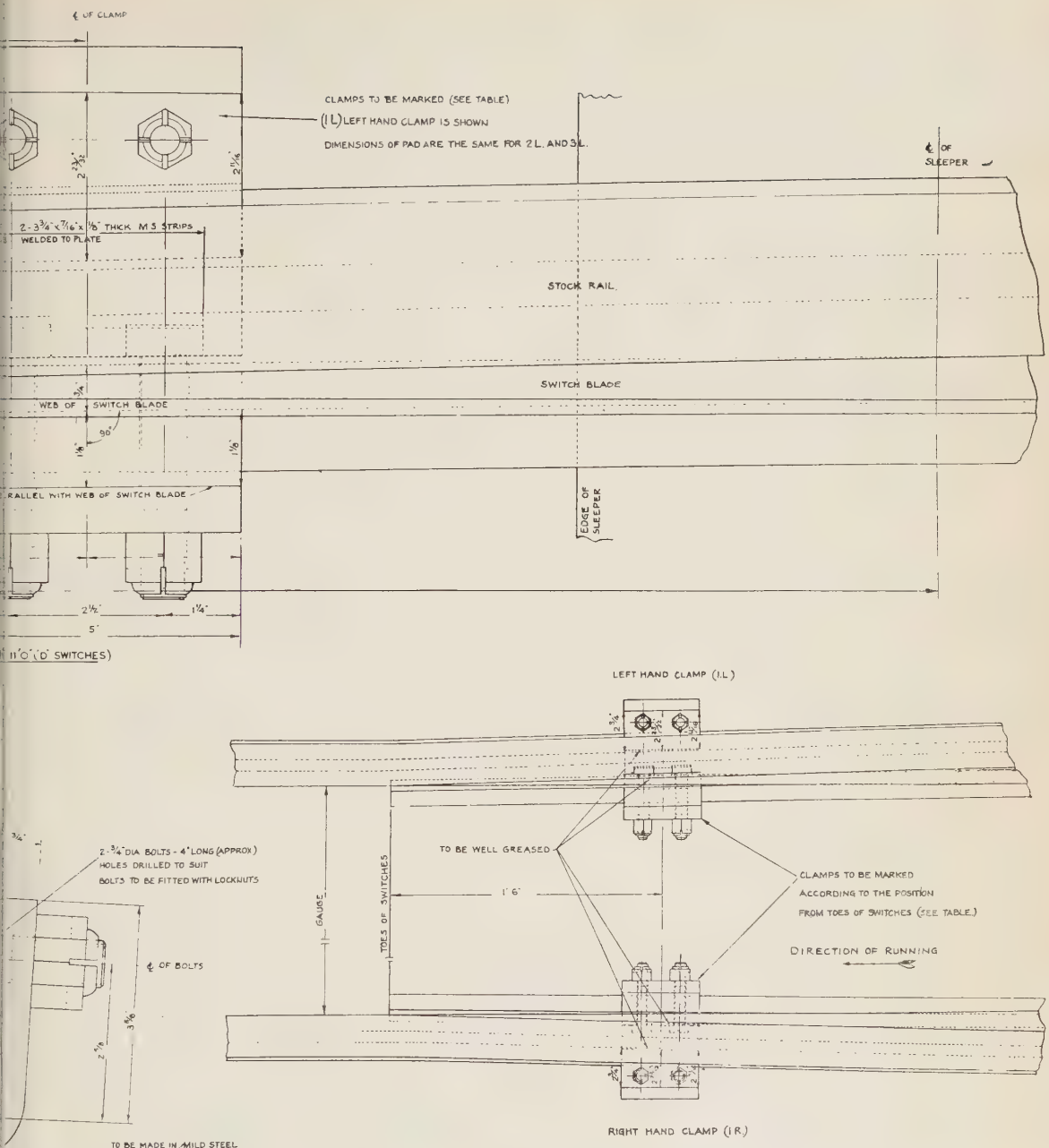
PART PLAN OF UNDERCUT SWITCH BLADE

'D' UNDERCUT SWITCH BLADE		MARKING OF CLAMPS	
DISTANCE FROM TOES OF SWITCHES TO CENTRE OF CLAMP	'A'	LEFT HAND	RIGHT HAND
1'-6"	6 1/16"	1.L.	1.R.
3'-9"	6 11/32"	2.L.	2.R.
8'-6"	6 13/16	3.L.	3.R.


19/16 ('D SWITCHES) AT 1'6" FROM TOE OF
A
STOCK RAIL
95 lbs PER YARD BSBH RAIL
WELD
2 4.5 MS PLATE
INCLINATION 1 IN 20
CF BOLTS
PAD MATERIAL TO BE DETERMINED
PAD CHAMFERED 1/4" AT 45°
1/4 RAD
2 - ½" DIA BOLTS 3¾" LONG (APPROX) HOLES DRILLED TO SUIT
BOLTS TO BE FITTED WITH LOCKNUTS

END ELEVATION CLAMP. (LEFT HAN

DIMENSIONS SHOWN ARE AT CENTRE L


℄ OF CLAMP
CLAMPS TO BE MARKED (SEE TABLE)
(1 L) LEFT HAND CLAMP IS SHOWN
DIMENSIONS OF PAD ARE THE SAME FOR 2 L. AND 3 L.
℄ OF SLEEPER
2-3¾" x 7/16" x ⅛" THICK M.S STRIPS WELDED TO PLATE
STOCK RAIL.
SWITCH BLADE
WEB OF SWITCH BLADE
90°
PARALLEL WITH WEB OF SWITCH BLADE
EDGE OF SLEEPER
2½"
1¼"
5"
11'0" 'D' SWITCHES)
LEFT HAND CLAMP (1 L)
2-¾" DIA BOLTS - 4" LONG (APPROX)
HOLES DRILLED TO SUIT
BOLTS TO BE FITTED WITH LOCKNUTS
℄ OF BOLTS
TO BE WELL GREASED
GAUGE
TOES OF SWITCHES
1' 6"
CLAMPS TO BE MARKED
ACCORDING TO THE POSITION
FROM TOES OF SWITCHES (SEE TABLE.)
DIRECTION OF RUNNING
RIGHT HAND CLAMP (1 R.)
TO BE MADE IN MILD STEEL
UNLESS OTHERWISE STATED
BLADE TO FIT AGAINST
FLANGE OF STOCK RAIL
ED ½ LESS THAN L.T.E. STANDARD
DOTTED
TOP OF SLEEPER

PLAN SHOWING No.1 RIGHT AND LEFT HAND CLAMPS.

SCALE. 3 INCHES TO 1 FOOT.

FOR ARRANGEMENT OF SPECIAL JOINT SEE DRG No.P. 2626.

NOTE

EXPANSION JOINTS TO BE STAGGERED 60 FEET APART.

(C) Expansion gaps. — Determination

Question	1. Temperatures and prescribed joint openings			
Railway	Length of rail	Temperatures and openings		
British Railways	60 ft.	Below 50°F = 3/8 in. (Frosty or cold)	50° — 75°F = 1/4 in. (Cold to warm)	75°F—100°F = 1/8 in. (Hot)
	Temperatures measured by special thermometers inserted into head of short pieces of rail carried to site of relaying.			
London Transport	60 ft.	Below 48°F = 1/2 in. (Frosty or cold)	49°—75°F = 3/8 in. (Cold to warm)	76°—100°F = 1/4 in. (Hot)
	Temperatures are rail temperatures.			
Pennsylvania Railroad	45 ft.	26°—50°F = 5/16″	51°—75°F = 1/4 in.	76°—100°F = 1/8 in.
	Temperature is measured by rail thermometer placed on the base of the rail close to the web on the side which is shaded from the sun.			
South African Railways	60 ft. to 120 ft.	25° — 44°F = 3/8 in.	45°—59°F = 5/16″ 60°—74°F = 1/4 in.	75°— 89°F = 3/16 in. 90°—104°F = 1/8 in.
	Temperatures measured by mercury bulb thermometer set in copper jacket, and laid directly in contact with the rail steel.			
Government of India Railways	42 ft.	(Typical allowances)		70°—85°F = 3/8 in. 85°—100°F = 5/16″
	Allowances in most districts relate to air temperatures.			
Nizam's State Railway	39 ft.			70°—89°F = 3/16 in. 90°—109°F = 1/8 in.
	Temperatures are measured by thermometer with bulb inside a block of rail steel about 3″ cube.			
Ceylon Government Railway	Expansion gap provisions are standardised on 1/8″ to 3/16″.			
Sudan Railways	36 ft.	Generally 1/4″		
Victorian Railways	90 ft. to 270 ft.		60°F = 7/16 in. 68°F = 13/32 in.	70°F = 3/8 in. 75°F = 5/16 in. 80°F = 1/4 in. 86°F = 5/32 in. 91°F = 3/32 in. 96°F = Nil
	45 ft.		40°—65°F = 1/4″	65°F—90°F = 3/16″
	Temperatures are rail temperatures measured with « Rototherm » thermometer.			

dard allowances.

	2. How were these dimensions established	3. Tolerances accepted for running track	4. Methods of restoring joint openings to dimensions
ver 100°F = None (very hot)	Study of cases of track buckling showed several contributory causes and it has not proved necessary to vary the prescribed expansion gaps.	It is not considered practical to lay down such tolerances.	If variation is due to rail creep, the rails are pulled back as required.
ove 100°F = 1/8 in. (very hot)	On experience.	Not defined.	As necessary, particularly in early spring, rails are pulled back.
ver 100°F = None	The openings provided take into account the expansion and contraction of the rail due to temperature variation and also movement of the rail due to traffic. They are the result of experience rather than any particular experiment.	No variations have been established.	Rails are driven back against shims of proper thickness. Additional rail anchors are applied.
°—124°F = 1/16 in. 125° = None	The gaps were determined from observations of these rails in service.	Left to discretion of district engineer.	Creep is pulled back.
°—115°F = 1/4 in. °—130°F = 3/16 in. °—145°F = 1/8 in. °—160°F = 1/16 in. ° and over = None	Based on experience — theoretically with range of 150°F a 42 ft. rail can expand 1/2in., if free. The standard joint provides for 1/2″ movement. In practice restraint exists and is more marked on steel and cast-iron sleepers.	Not defined.	Pulling back is done and additional anti-creep devices are introduced.
°—129°F = 1/16 in. ° and over = None.	From experience only.	0—1/2 in.	Immediate action to equalise expansion gaps.
	From practical experience of track behaviour under local conditions.	0-3/4″	Range of daily temperature is utilised, or in the case of large excesses by pulling back.
er 96°F = None ver 90°F = 1/8″	By calculations from coefficient of expansion and from practical experience.	0—7/16″	Joint expansions are adjusted by creep jack and expansion keys.

appears to be thought necessary for use with long welded rails. Anti-creep devices are mentioned by only two administrations which is consonant with the experimental verification that the grip of most fastenings is normally stronger than that of the resistance to movement of the sleeper in ballast, (See Figures 13 and 14), except where rail creep is produced by traffic conditions.

(*n*) Sleeper spacing at welds can be the same as at intermediate positions.

(*o*) Crushed stone is the preferred ballast and there is a general tendency to increase the width of shoulder ballast with welded rails.

(*p*) With the normal length of welded rail up to 270 feet, joints of the ordinary kind with normal expansion movement appear to be adequate. With lengths in excess of 270 feet there appears to be a requirement either for the de-stressing of the rails at a mean of the annual temperature to limit the breathing movement, or for the provision of joints which can accommodate excessive rail movement without shock to vehicles.

(*q*) No requirement for special weld inspection routines has yet been found necessary so far as rails in service are concerned, but the short period during which flash-butt welded rails have been installed is not yet sufficient to preclude the possibility of ageing effects which may render such inspection provisions necessary.

(*r*) There seems to be general evidence that most forms of track, if well ballasted and properly maintained, can withstand a temperature rise of the order of 60°F, so that continuous welding of track keyed up at a mean annual temperature is a general possibility.

(*s*) The replies indicate that there is a need for large scale carefully measured field tests with welded track in order to establish the limits of safe practice, and to clarify the conditions of installation, to which particular track standards are best adapted for the use of welded rails.

There is a similar need for assessment of the economic value of welded rails through the careful compilation of cost statistics covering the whole life of a sizeable stretch of welded track.

***

(C) — Expansion gaps : Determination of standard allowances.

(1) *Give for different types and lengths of rail, a table indicating the prescribed joint opening in relation to temperature. State whether this relates to the temperature of the rail or the air temperature and say how this is measured.*

Answer. — See Table 10.

(2) *How were these dimensions established :*

(*a*) *Were they set up following special experiments? If so, describe these experiments with particulars of the track, rails, sleepers, ballast, direct or indirect fixings of the rail to the sleepers, the use of rail anchors, etc.*

(*b*) *Were the prescribed rail gaps set up following special observations on track in normal use? If so, describe the extent and number of these investigations, and the nature of the lines and traffic involved. Give particulars as in (a) above of the track concerned.*

(*c*) *Were the dimensions derived from calculations which took account, not only of the free expansion of the rail, but also of the possibility of constraint? Have divergencies from the calculated results been encountered in observations of track in service?*

Answer. — See Table 10.

(*a*), (*b*) and (*c*). Apart from a special experiment carried out in 1933 by the South African Railways these dimensions have been established as a result of practical experience and from normal observations of track under service conditions. The experiment referred to by the South African Railways relates to 80 lbs. per yard bull head rail keyed into chairs as in normal construction.

« In order to obtain an accurate record of the expansion of the rails, wooden blocks were first sunk into the foundation to act

as bases. To these wooden blocks, which were placed one at each end of a rail, were attached recording boxes in which a strip of paper was moved continuously under a pen. »

« The pen was attached to one end of a lever arm with fulcrum on the wooden block. The other end of the lever arm was split to form a U through which passed a rod which was fixed to the rail, fitted the U exactly, but was free to move in the U in a vertical direction. The lever arm magnified the movement of the rail end 10 times. The two rods were fixed to points on the rail 37 feet apart so that the total expansion recorded was for a length of 37 feet.

» A record of the maximum and minimum temperatures, during the test, was kept by means of a suitable thermometer.

» The record of the movement of the rail on one recorder was very nearly a straight line, indicating that the rail was only expanding in one direction. This was the direction which tended to loosen the keys.

» The average co-efficient of expansion as worked out from several tests was approximately .000012 per degree centigrade.

» Using the co-efficient of expansion .000012 the following gaps are obtained, which accord closely with current practice. »

Temperature degrees Fahrenheit	Gaps 40-ft. Rail
25	.32 (5/16″)
50	.24 (1/4″)
75	.16 (5/32″)
100	.08 (3/32″)
125	.00 (Nil)

« The expansion of the rail in the track brought out another interesting fact. The expansion that takes place does so in the direction which tends to loosen the keys. Keys are generally tightened during the day time, that is, at a time when the expansion in greatest. When the keys have been hammered home it is impossible for the rail to resume its original position when contracting, with the result that a certain amount of creep, due to temperature changes, can be expected on chaired tracks. »

(3) *Set out the tolerances accepted for the joint openings in ordinary running track.*

Answer. — See Table 10.

In general specific tolerances are not the subject of particular regulations, but are left to the discretion of the local engineers.

(4) *When the tolerances are exceeded what steps are taken to bring the joint opening to the standard dimensions?*

Answer. — See Table 10.

Methods include drawing or driving back the rails as required, and the use of anti-creep devices where this is judged to be of value.

SUMMARY.

The prescribed joint openings appear to conform reasonably to theoretical calculations in relation to temperature ranges, and vary from a maximum of 1/2″ for temperatures below 50°F in the case of London Transport to a minimum of zero for unwelded rails in the case of British Railways and the Pennsylvania Railroad at temperatures in excess of 100°F.

It is not clear, however, from the replies how rigidly these prescribed openings are observed in actual practice. It is known for instance that a casual observation of the track will often show considerable variation of rail gap dimensions over a short distance. The facts that these divergencies are not normally accompanied by serious risk of distortion and that the restoration of gaps is not infrequently a laborious operation, may account for the reliance placed upon local observation and adjustment. It is generally recognised that special care must be given in these matters during rapid seasonal increases in temperature, particularly when the daily range of temperature is considerable.

[656 .25]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION IX.

Modern safety and signal installations (centralising apparatus for block system and signals). — Central electric apparatus with individual levers and « all relay » levers (all electric interlocking). — Automatic block-system with continuous current and coded current. — Light and speed signalling.

REPORT

(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan),

by H. H. Dyer, M.I.E.E.

Chief Executive Officer Engineering (Signals & Telecommunications). The Railway Executive, British Railways, London.

The following Railways gave replies to the Questionnaire :

Bombay, Baroda and Central India Railway;
British Railways;
London Transport Executive;
New Zealand Government Railways;
Pennsylvania Railroad;
South African Railways and Harbours;
Victorian Railways.

A. — Centralised electrical operation of signals with interlocking levers or with free push button or switch system.

Question 1. — *What system do you prefer in the case of large installations; for what reason?*

There has not been sufficient experience of free push button and switch systems for a definite opinion to be expressed as to the preference for these systems or for the interlocking lever system. The general opinion seems to be that whilst the push button and switch systems, which are usually of the automatic route setting type, are favoured from an operation point of view, the circuits of the interlocking lever system are somewhat simpler at large installations. The Pennsylvania Railroad says that the chief reason for using the interlocking lever system is that the push button types are usually more expensive and the additional cost cannot be justified economically.

Question 2. — *Do you prefer mechanical or electrical interlocking, where individual levers are used?*

Opinion is divided as to the preference

for mechanical or electrical interlocking where the interlocking lever system is used but the majority of the Railways seem to prefer electrical interlocking.

Question 3. — *Do you make use of selection in order to reduce the number of levers, e. g. one lever to work a signal controlling several routes?*

It is common practice of all Railways to make use of selection to reduce the number of levers where the interlocking lever system is used. By this means, using one lever to operate signals controlling several routes, the size of the lever interlocking frame can be restricted, thus meeting one of the objections hitherto raised against the lever interlocking system.

Question 4. — *If push buttons are used, are these fitted on a geographical panel or a separate desk panel?*

At small installations of the push button or switch systems it is usual to fit the push buttons or switches on a geographical panel. At large installations they are some times fitted on a geographical panel and at others on a separate desk panel. At very large interlockings it is sometimes difficult to arrange a geographical panel so that all push buttons or switches can be reached conveniently for operation. In some cases the panel is divided into sections so that the push buttons or switches are all within easy reach. Where this is not practicable they are fitted on a separate desk panel.

It is the intention of the New Zealand Government Railways to mount the buttons on a separate desk in new installations. The Pennsylvania Railroad have a system of free levers using non-interlocked miniature levers, the interlocking being accomplished through relays. This relay interlocking system is somewhat similar in principle to relay interlocking systems using free switches or push buttons. Automatic route setting can, of course, be employed with miniature levers as well as with the push button or switch systems.

Question 5. — *Is it possible to make an automatic selection of the possible routes between two points, so that the first free route is chosen, according to an order laid down in advance? What system is used?*

Although it is practicable to arrange for automatic selection of two or more possible routes between two points there are only a very few installations incorporating this feature. If the push button system were employed on the Pennsylvania Railroad it would be their intention to arrange to automatically select the preferred route and in case this route was in use the second route would be automatically selected. This feature has not been employed in push button or switch systems on British Railways. In cases where the track layout would permit of it, it has to be considered whether the facility would justify the additional complications to the electrical circuits.

Question 6. — *Compare the technical advantages of the two systems.*

In order to compare the technical advantages of the different systems it is necessary to have had experience in operation over a number of years. A considerable number of installations of the interlocking miniature lever system have been in use on British Railways for many years and have given excellent results. A number of different types of push button and switch systems have recently been installed but it is considered too early to assess the relative technical advantages.

The Pennsylvania Railroad points out that the interlocked lever system involves technical problems in the design and manufacture of the interlocking machine which do not arise with the push botton system. On the other hand, whilst the push button system has less mechanism than the interlocking machine, it has two to three times the number of controlling relays and electrical circuits.

The South African Railways consider that as the circuits of the interlocked lever system are simple and the apparatus straight forward it is easier to alter, both from the

Drawing Office and installation point of view. Also, special apparatus must be used for relay interlocking systems.

Question 7. — *Is it not a fact that greater technical knowledge is necessary for the staff maintaining push button installations?*

It is the general opinion that greater technical knowledge is not necessary for the staff maintaining push button installations. However, as the push button system involves a much larger number of circuits and relays associated therewith, proper training of the staff is necessary.

A point which has to be considered is that with a number of different systems in use maintenance staff transferred from one system to another have to learn a new system. Interlocked lever systems are fundamentally the same wherever they may be and only differ in detail from place to place.

Question 8. — *In view of the more complicated mechanism of push button systems, what steps have you taken to assure their proper maintenance?*

Proper maintenance of the more complicated push button and switch systems is assured by selection and training of the staff, periodical inspection and periodical relay overhauls.

Question 9. — *Make the comparison of the two systems from the points of view of prime cost and maintenance.*

There is little difference in the overall prime cost of the two systems, including the signal box and relay room. Investigations by the Pennsylvania Railroad indicate that the prime cost of the push button system would be about 10 % to 15 % higher than the interlocked lever system.

The cost of day to day maintenance is about the same for the different systems but the number of relays requiring periodical overhaul is considerably greater in the case of the push button and switch systems.

Question 10. — *Does a breakdown in a push button system have greater repercussions on the operating and traffic than a breakdown in a interlocking system?*

It does not appear that generally with such failures as have occurred, a breakdown in a push button system has had greater repercussions on operating and traffic than a breakdown with an interlocked lever system. The New Zealand Government Railways say that there are greater repercussions with a route setting system. This is to be expected with some types of failure in the route setting circuits as one contact or wire may be common to several routes whereas where points are individually controlled by levers the effect of a failure is generally localised.

One point which is often overlooked is that when a failure does occur in an interlocked lever system it is often possible, by taking simple precautions, to continue to operate traffic safely if the levers can be operated and so provide through the interlocking, the necessary security against conflicting routes being set up. In relay interlocking systems, where the push buttons or switches are free to be operated at any time, security cannot be given in this way and special precautions have to be taken which can cause additional delay to traffic.

As an example of this, on British Railways it is laid down that where a facing point is out of order and has to be disconnected, the stop signal concerned must be maintained at Danger and a hand-signalman placed at the signal to act under the signalman's instructions. Before a train is brought forward, the handsignalman must satisfy himself that any facing points concerned are in their proper position and secured by clip or scotch.

Where there are a number of facing points in the route concerned, considerable delay is occasioned by the carrying out of this rule. Where the points are individually operated from interlocked levers and only one of the points has failed, it is permissible, where special instructions are issued, to clip only the points which have failed and, provided that all the levers are operated

to their correct positions, including the lever controlling the stop signal concerned (although the signal itself is maintained at Danger), a train may be brought forward past the signal.

The operation of the levers assures that the route is correctly set and held and that conflicting movements cannot be made. As this safeguard cannot be provided with relay interlocking systems no such dispensation can be given and the full provisions of the rule must be carried out.

Question 11. — *What are the advantages and drawbacks of electrical control and electro-pneumatic control of the points?*

From an operating point of view, there is little to choose between electrical operation and electro-pneumatic operation of points except that the latter is a second or so quicker. This slightly quicker operation may be of advantage in special cases. The electro-pneumatic point operating equipment is simpler than the all electric equipment but requires compressor plant, tanks, coolers and air mains in addition to the electric control and indicating circuits. There are certain objections to the piping for air mains particularly in electrified areas where the running rails are used for traction current return. Where the track layout is complicated and there is insufficient room to fix electric point operating machines in the desired positions, the smaller size of electro-pneumatic point operating mechanism is an advantage.

The Pennsylvania Railroad is the only one expressing a definite opinion in favour of electro-pneumatic operation. They say that electro-pneumatic operation of the larger interlockings is considered more economical, provides faster operation, and is more reliable more rugged, and will withstand the heavy service required with less maintenance and less trouble.

Question 12. — *What steps have you taken to avoid having to use temporary signals when the points have been run through in the wrong direction and damaged?*

Facing points are fitted with detectors so that if the tip of the closed switch is more than about 1/8 inch from the rail, any signals permitting a train to pass over the points are prevented from operating to a « Proceed » position. This is general practice and would apply if the points had been trailed through and damaged so that the end of the closed switch was standing away from the rail.

***

B. — **Distant control and operation of points and signals by means of relays.**

Question 1. — *To what extent have you made use of the system :*

a) *on single track lines;*

b) *on double or multiple track lines?*

Apart from the American Railways, remote control of points and signals by relay systems has not been used to any great extent on single track lines. There are several instances on the New Zealand Government Railways of remote control of junctions and sections by C. T. C. equipment and on the Victorian Railways some points and signals at unattended crossing loops on single lines are remotely controlled from the signal box at one end of the section. The Pennsylvania Railroad has 412 miles of C. T. C. in service where train movements into and out of sidings are controlled from a central point.

The Pennsylvania Railroad also has 188 remotely controlled interlockings on double or multiple track lines but the coded relay system of remote control is not used by other Railways on double or multiple track lines.

Question 2. — *What signalling system did it replace :*

a) *on single track lines;*

b) *on double or multiple track lines?*

On single track lines the remote control system has, where used, replaced manual block, electric staff, tablet and token

working, and on the American Railways manual block and the « Train Order » system.

On double or multiple track lines it has replaced control from a local signal box.

Question 3. — *For what reason has it been used?*

The system has been used to effect economy, to speed up operation and to increase safety where points were formely hand operated and no interlocking protection existed. On the American Railways operation was speeded up by eliminating train stops to operate hand points.

Question 4. — *Do you intend to extend it?*

It is the general intention to extend the system as circumstances warrant. Although the system has been little used except in America where special conditions exist, this is because a case has not been made out for it except under special circumstances.

Question 5. — *What are the principal advantages?*

The principal advantages, where it has been justified are saving in operating costs and speeding up operation. In the American case, where points were hand operated and no interlocking protection existed, increased safety was provided in addition to the speeding up of operation.

Question 6. — *What arrangements have been made to ensure the efficient maintenance of the equipment?*

Except in the larger installations no special maintenance arrangements have been found to be necessary. Regular inspection, overhaul and test of the equipment is required as with other electrical signalling equipment.

Question 7. — *Do you have any difficulty in getting suitable staff for such maintenance work?*

It is the general experience that there is no particular difficulty in obtaining suitable staff for the maintenance of this special equipment except where there is a general shortage of skilled labour. Staff are usually suitably trained for the work.

***

C. — **The automatic block with track circuits using a permanent or coded flow of current.**

Question 1. — *Do you make use of track circuits worked by permanent or coded current for the automatic block signals?*

What do you consider the maximum length advisable for the track circuits in each case?

What shunt is obtained by the train with track circuits of 500, 1 000, 1 500 and 2 000 m (546, 1 093, 1 640 and 2 187 yards) with :

a) direct current;
b) alternating current without inductive connections;
c) alternating current with inductive connections;
d) coded current.

Apart from the American Railways where coded current track circuits are used fairly extensively, permanent current track circuits are used almost exclusively though several experimental installations of coded current track circuits are in use.

It is impossible to say what maximum length of track circuit is advisable as this depends upon the ballast conditions and type of rail fastening, e. g. screwed to the sleepers or bolted through the sleepers. It is generally considered that on good track with screw fastenings the maximum length for permanent current track circuits should be about 3 000 feet though the Victorian Railways and the Pennsylvania Railroad consider about 6 000 feet the maximum length advisable. The Pennsylvania Railroad consider 11 000 feet to be the maximum length for coded current track circuits.

The train shunt is governed by the maximum variation in the ballast resistance and by the minimum value to which this falls.

Under conditions of maximum ballast resistance the train shunt cannot be higher than the minimum value to which the ballast resistance falls. The train shunt is therefore not governed by the length of a track circuit alone. Consequently train shunts for track circuits of various lengths cannot be given.

On a good track circuit, where the variation in ballast resistance is very small, the train shunt of a direct current track circuit or an alternating current track circuit without impedance bonds may be several ohms. On bad track circuits the train shunt often falls below one ohm, as it does on alternating current track circuits using impedance bonds.

It is fairly general practice to lay down a minimum value below which the train shunt should never fall. On British Railways the minimum allowed for all track circuits is 0.5 ohm except for alternating current track circuits using impedance bonds where it may be allowed to fall to not less than 0.3 ohm. The South African Railways lay down a minimum of 0.5 ohm for all track circuits and the New Zealand Government Railways give values of from 0.3 ohm to 1 ohm with track circuits half a mile long. The Bombay, Baroda and Central India Railways give the shunt obtained with track circuits 546 yards long as between 4 and 8 ohms for direct current. 0.3 ohm for alternating current and 0.2 ohm for alternating current with impedance bonds. The Victorian Railways permit a minimum of 0.1 ohm for direct current track circuits and the Pennsylvania Railroad stipulate that the train shunt for all types of track circuits shall be not less than 0.06 ohm.

Question 2. — *What are the advantages of coded current track circuits?*

Some of the advantages of coded current track circuits are that longer track circuits are possible, they are less likely to be wrongly affected by foreign currents and faulty insulated rail joints, and line wires are not necessary for signal control.

Question 3. — *What economies do you expect to obtain to make good the extra cost of coded current track circuits?*

The possible use of longer track circuits and the saving in line wires may result in economies in certain cases, particularly where some systems of speed signalling are used. The same economy in line wires would not be effected in the case of a simple signalling system such as is used on British Railways.

Question 4. — *What confidence have you in the two systems from the point of view of safety and regularity?*

The general opinion is that there is full confidence in the correct operation of permanent current track circuits and of coded current track circuits both from the point of view of safety and regular operation. In theory, the coded track circuit being less likely to be wrongly affected by foreign currents, there is some increase in safety but appropriate steps are taken with permanent current track circuits to avoid this possibility.

Question 5. — *Are the track circuits supplied with current from the railway supply, through a substation, of from batteries?*

It is the general practive where a power supply is readily available, either from the Railway supply or from a public supply, to operate direct current track circuits from trickle charged secondary batteries. In the majority of cases, where a power supply is not readily available, direct current track circuits are operated from primary batteries.

Alternating current track circuits are operated from Railways supplies, generally from separate signalling mains from the substations, where such a supply is available. In other cases public supplies are used.

Question 6. — *What is the average distance between the signals?*

The distance between signals in auto-

matic block territory is, of course, dependent on the density of traffic and the headway required. It varies from as much as 5 miles on single lines on the New Zealand Government Railways to as little as 50 yards in some cases on the London Transport Railways.

To give the average distance between signals would therefore convey very little information. The Bombay, Baroda and Central India Railway give an average distance of 2 000 feet, British Railways 600 feet to 2 400 feet on suburban lines, Pennsylvania Railroad 10 000 feet, South African Railways 600 feet to 6 000 feet and the Victorian Railways 900 feet in metropolitan areas and 1 mile on certain country lines.

Question 7. — *What frequencies are used and what precautions do you take to prevent the coded current of a track circuit affecting that of the adjoining track circuit should the insulated rail joint get broken?*

The coding frequencies used are, 75, 120 and 180 per minute. In order to prevent the coded current of a track circuit affecting that of the adjoining track circuit should the insulated rail joint break down, adjacent track circuits are arranged so that the polarity of the coding current is staggered in a similar manner to ordinary alternating current track circuits. Where the alternating current coded system is used by the Pennsylvania Railroad, lock out protection is provided in which energy from an adjacent track circuit energises the track relay continuously.

Question 8. — *What type of insulated rail joint do you use?*

For insulating the rail joints most Railways use fibre plates between the fish plate and the rail, fibre bushes in the bolt holes and fibre plates between the rail ends. British Railways also use an insulated joint known as the « Williams » joint but are now using a solid fish plate made of laminated insulating material.

Question 9. — *What is the average number of breakdowns of all kinds per signal and per year for your automatic block installations?*

The average number of breakdowns of all kinds per signal per year on automatic block installations is less than one on all Railways. Typical figures are 0.6, 0.33, 0.21 and 0.15.

Question 10. — *How does the signalman in charge of a junction on a line fitted with the automatic block know the direction of a train approaching one of the two branches of the junction has to take?*

On lines operated on the automatic block system the signalman in charge of a junction is informed of the direction which an approaching train must take by means of bell codes given from the previous signal box or by train describers. On multiple track lines where a number of trains may be approaching simultaneously on adjacent track, train describers are necessary.

Question 11. — *When the automatic block is used, drivers are allowed to run past certain signals at danger but not others. How is the driver to be made to know when he is allowed to run past a signal at danger?*

There are three systems as follows, under which a driver is permitted to pass a signal at danger :

(*a*) Automatic signals may be passed at danger under certain rules but controlled signals may only be passed at danger by specific instruction. Automatic signals are distinguished by a letter « A » on the signal. Controlled signals which become automatic when a signal box closes are indicated by an illuminated letter « A » when working automatically;

(*b*) Automatic signals which may be passed at danger under certain rules are distinguished by a marker light fixed below the main signal. In most cases the marker is a red light. Where the red marker light is vertically under a red light in the main signal, the meaning is « Stop and Stay » and a driver is not permitted to pass such a signal at danger. Where the red marker light under a red light in the main signal is to one side, the meaning is « Stop and

Proceed » and the signal may be passed at danger.

(*c*) On British Railways telephones are provided at automatic signals and at certain controlled signals, giving independent telephone communication to the next open signal box ahead. Drivers are not permitted to pass a signal at danger except by permission of the signalman. The controlling track circuits are indicated in the signal box.

***

D. — **Light signals, signalling for direction and speed.**

Question 1. — *Do you find it necessary to give drivers direction indications? When do you do so, and how? What are the advantages?*

There are two distinct schools of thought as to the desirability of giving to drivers an indication of the direction in which a train is routed at a diverging junction. Those Railways which use a system of speed signalling, such as the American, New Zealand and Victorian (Australia) Railways do not give such a direction indication but rely on a reduced speed indication for the lower speed routes. Other Railways such as the British, Indian and South African Railways, who do not use a system of speed signalling, give direction indications at diverging junctions.

Direction indications of a divergence are given at the signal immediately on the approach side of the junction by means of a row of white lights inclined at an angle of 45, 90 or 135 degrees on either side of the vertical. In the case of the South African Railways an indication of the straight, high speed, route is also given by means of a row of white lights in a vertical line.

The advantages claimed for direction indications are that a clearer indication is given to the driver of the route which he is to take, he knows in which direction he is routed and is better able to judge how to control his speed over the junction.

Question 2. — *Show by means of diagrams the aspects given by a series of signals and explain the meaning of these different aspects.*

The number of running signal aspects displayed to a driver varies from the four used in the British system, together with a direction indication; to a larger number of aspects necessary with a system of speed signalling such as is used on the New Zealand and American Railways.

The four running aspects of British Railways and their meanings are :

A single red light.	Danger. — Stop.
A single yellow light.	Caution. — Be prepared to stop at the next signal.
Two yellow lights vertically displayed.	Preliminary Caution. Prepare to pass next signal at restricted speed and to find it showing one yellow light, or two yellow lights in certain cases in closely signalled areas.
One green light.	Clear. — Next signal exhibiting a proceed indication.

In certain suburban areas where the braking distance required is short, only three of these aspects are used : Red (Stop), Single yellow (Caution) and Green (Clear).

The following are the main running aspects of the speed signalling system used by the New Zealand Government Railways :

Red light over Red light.	Stop.
Red light over Yellow light.	Caution. — Proceed at medium speed prepared to stop at next signal.
Red light over Green light.	Clear. — Proceed at medium speed. Next signal at « Caution » or « Clear for medium or normal speed ».

Yellow light over Red light.	Caution. — Proceed at normal speed prepared to stop at next signal.
Yellow light over Green light.	Clear. — Prepare to reduce to medium speed. Next signal at « Caution » or « Clear for medium speed only ».
Green light over Red light.	Clear. — Normal speed. Next signal at « Caution » or « Clear for normal speed ».

Each of the above aspects is a combination of two lights whereas those American Railways who use colour light signals have a system embodying three lights covering four distinct speeds (Normal, Limited, Medium and Slow) as follows :

Red light over Red light over Red light.	Stop.
Yellow light over Red light.	Slow Approach. — Proceed preparing to stop at next signal. Slow speed within interlocking limits.
Red light over Red light over Green light.	Slow Clear. – Proceed. Slow speed within interlocking limits.
Red light over Yellow light over Green light.	Medium Approach Slow. — Proceed at medium speed approaching next signal at Slow Speed.
Yellow light over Red light over Green light.	Approach Slow. — Proceed approaching next signal at slow speed. Train exceeding medium speed must at once reduce to that speed.
Red light over Yellow light over Red light.	Medium Approach.— Proceed at medium speed preparing to stop at next signal.
Red light over Yellow light over Yellow light.	Medium Advance Approach. — Proceed preparing to stop at second signal. Medium speed within interlocking limits.
Red light over Green light over Red light.	Medium Clear. — Proceed. Medium speed within interlocking limits.
Yellow light over Green light over Red light.	Approach Medium.— Proceed approaching next signal at medium speed.
Green light over Yellow light over Red light.	Advance Approach Medium. — Proceed approaching second signal at medium speed.
Yellow light over Green light over Green light.	Approach Limited. — Proceed approaching next signal at limited speed.
Red light over Green light over Green light.	Limited Clear. — Proceed. Limited speed within interlocking limits.
Yellow light over Red light over Red light.	Approach. — Proceed preparing to stop at next signal. Train exceeding medium speed must at once reduce to that speed.
Green light over Reg light over Red light.	Clear. — Proceed.

This system of speed signalling with colour-light signals has been based on the night indications of the equivalent semaphore signals.

The light signalling system used by the Pennsylvania Railroad is unique in that instead of using colour-light signals they have position-light signals consisting of a row of three amber coloured lights in hori-

zontal line, vertical line or at 45 degrees, the running signals having the following meanings :

○○○ = Stop-signal.	Stop.
○○○ = Restricting.	Proceed at restricted speed.
○ = Caution.	Train exceeding medium speed must at once reduce to that speed. Where a facing switch is connected with the signal, approach that switch prepared to stop. Approach next signal prepared to stop.
○○○ = Slow Approach.	Proceed prepared to stop at next signal. Slow speed within interlocking limits.
○ = Slow Clear.	Proceed. Slow speed within interlocking limits.
○ = Approach Slow.	Proceed approaching next signal at slow speed. Train exceeding medium speed must at once reduce to that speed.
○○○ = Medium Clear.	Proceed. Medium speed within interlocking limits.
○ = Approach Medium.	Proceed approaching next signal at medium speed.
○ = Approach.	Proceed prepared to stop at next signal. Train exceeding medium speed must at once reduce to that speed.
○ = Clear.	Proceed.

Question 3. — *At a junction where the direction is signalled, the driver knows what direction he must take. With speed signals, he does not. Has it been proved that this is a drawback?*

Those Railways which use a system of speed signalling and therefore do not give to a driver a direction indication of a divergence at a junction, do not consider that the absence of such an indication is a drawback. The comment of the Victorian Railways on this point is of interest. They say : « If the junction consists of a straight route and a diverging route, the speed signal indication is considered sufficient, but if neither route is straight, the medium speed indication is displayed for either route and may at times lead to a wrong route, but the driver knows which route he is to take and travelling at medium speed he could generally see which way the points are set and stop his train if it should be wrongly routed. » This infers that with a simple junction where one line is a high speed route and the other a low speed route the driver does indirectly get an indication of the route set up but where neither route is a high speed one the absence of such an indirect indication of direction might lead to a train being sent in the wrong direction. It is not considered that a driver would be able to see which way the junction points were set in time for him to stop before passing over the points.

Those Railways which give direction indications have no proof that the absence of such indications would be a drawback. It is, however, felt that if a junction were set for the wrong direction and the driver was not aware of this he would naturally proceed

in the wrong direction and delay would be occasioned by having to get the train back on to its right route. Cases have occurred where a driver, seeing from the signal indication that the junction has been set for the wrong direction, has stopped before reaching the junction.

Question 4. — *What type of light signals do you use? With special red, yellow or red lenses, or the system making use of 2 or 3 light frames containing coloured glasses? Give the reasons for your choice.*

Most of the Railways answering the Questionnaire use both multi-unit type with separate green, yellow and red lenses and the « Searchlight » type with moveable vane containing green, yellow and red glasses. It is claimed for the « Searchlight » type that they are more compact, phantom indications are avoided and in the case of South Africa the illumination is better under their conditions. No particular claims are made for the multi-unit type but it seems preferable from a maintenance point of view to use this type with a relay controlling it rather than have the mechanism in the signal unit at the top of a post.

The Pennsylvania Railroad uses position-light signals with three amber coloured lights in a row. The reasons for their choice were :

(*a*) Most efficient signal during foggy or inclement weather conditions;

(*b*) Most economical in providing prescribed indications with minimum number of working arms;

(*c*) Indications displayed by position of lights rather than colours, eliminating possibility of a mistaken colour indication.

Question 5. — *What system do you use to make sure visibility is good at the foot of the signal? (« close up indication »).*

It is almost universal practice to use deflecting prisms for giving a close up indication. In certain instances separate side lights are also used, particularly in the case of electric trains where the motorman's cab stands right up to the signal.

Question 6. — *What type of lamps do you use : with one or two filaments? Give the power and voltage of the lamps? What optical system is used : diameter of the outer lenses, horizontal and vertical dispersal?*

The usual voltage rating of signal lamps is 12 volts except on the Victorian Railways who use both 6 volts and 10 volts. Most Railways use both single and double filament lamps. The power of the lamp is usually 18, 24, 25 or 33 watts for multi-unit type signals and 12 watts for « Searchlight » signals though lamps of lower power are sometimes used. For their position-light signals the Pennsylvania Railroad use single filament lamps with a rating of 12 volts 9 watts.

Question 7. — *Are the signals worked directly from the signal boxes or are relays used at the foot of the signal? Do you repeat the signal lights in the signal box?*

The optical system of multi-unit type signals comprises a coloured inner stepped lens of 5 1/2 inches diameter close to a prefocussed lamp, and a clear outer stepped lens 8 3/8 inches diameter. In order to avoid phantom indications reflectors are not used in multi-unit type signals. Specially designed reflectors are used in the « Searchlight » type signals and the movable vane containing the coloured glasses is located between the reflector and a small clear inner lens. The clear outer lens is 8 3/8 inches diameter and is either of the stepped or bullseye type.

The horizontal dispersal of the normal lens used in the multi-unit type signal is about 5 degrees and the vertical dispersal is about 2 degrees. the difference between the horizontal and vertical dispersal being due to the use of a lamp with a horizontal filament. The dispersal is less in the case of « Searchlight » signals, depending on the type. The optical system of some « Searchlight » signals specially designed to give an adequate light beam intensity with a low-powered lamp has a dispersal of only about 2 degrees. Specially designed outer lenses giving an increased horizontal

dispersal are used where required, such as where the approach to the signal is on a severe curve.

The optical system used by the Pennsylvania Railroad for their position-light signals consists of a reflector at the back of the lamp, a clear deflecting prism, having an 18 degree horizontal spread and a 20 degree downward deflection, in front of the lamp and an amber coloured conical outer cover glas 5 3/8 inches diameter in front of the deflecting prism.

Question 8. — *Do you check the lighting of the signal lights before allowing the upper lights to be lighted? If so, what system do you make use of?*

It is the usual practice of British Railways to prove the lighting of single-filament lamps by means of a relay in series with the lamp or lamp transformer. Double-filament lamps are not usually proved but there is a system of periodical lamp changing. Where direction indicators are used a sufficient number of lamps are proved alight in the direction indicator before the signal can change to a proceed indication.

Apart from the Indian Railways it is not the general practice of other Railways to check the lighting of the signal lamps. On the South African Railways signal lights are only checked where a « Searchlight » signal is used in conjunction with a route indicator.

Question 9. — *Do you use winking lights? If so, for what reason and at what periodicity?*

None of the Railways reporting use winking lights except the Pennsylvania who use them only for displaying a « Train Order » signal to convey information to the drivers that orders will be delivered. The periodicity is 30 flashes per minute.

Question 10. — *What precautions do you take to prevent the yellow light being confused with the red, and vice versa?*

Rigid specification of the colours of the red and yellow lenses or glasses ensures that the yellow light shall not be confused with the red and vice versa. Most Railways use British Standard Specification No. 623. The specification used by the Victorian Railways is modified to cover British and American Specifications and ensures sufficient discrimination in colour and brightness to prevent confusion.

Question 11. — *Are you proposing to use light signals systematically on your electrified lines?*

It is the general intention to use light signals systematically on electrified lines. The South African Railways consider it almost essential to use light signals on multi-track lines but semaphore signals are used to a large extent on double lines.

Question 12. — *If the electrification is being carried out with overhead lines, will the signals be fastened to the catenary posts? Are there any drawbacks to this?*

In electrified areas where the overhead system is used it is not the practice to fix signals to the catenary posts where this can be avoided except in the case of the Pennsylvania Railroad. Where there are a number of tracks, however, and there is not sufficient space between the tracks to fix the signals, they are fixed to the overhead structures. It is the general opinion that it is cheaper to use an independent post for the signal than to provide special fittings for fixing to the catenary posts. Also it is usually better for correct sighting of the signals. The Pennsylvania Railroad usually supports the signals on the catenary structure both overhead and at the side of the tracks. They claim that this practice results in some economy.

Question 13. — *Do you use special signals for trains running in the wrong direction on one of two tracks in the case of an electrified line, to enable maintenance of the catenary lines to be carried out with one line temporarily out of service?*

None of the Railways use special signals for trains running in the wrong direction on one of two tracks on electrified lines to enable maintenance of the catenary lines to be carried out on the other track. In some cases tracks are normally signalled for train movements in both directions.

[624 & 691]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION I.

Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.

REPORT

(America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan),

by A. Dean, M. Sc., D.I.C., M.I.C.E.

Chief Officer, Engineering (Works), The Railway Executive, London.

FOREWORD.

This report incorporates replies received to the questionnaire from the following administrations :

British Railways. — The Railway Executive.

London Transport Executive.

The Pennsylvania Railroad Company.

India Railway Board.

H. E. the Nizam's State Railway, India.

South African Railways, Harbours & Airways.

The Sudan Railways.

Victorian Railways, Australia.

Except where special reference is made to the contrary, the views expressed on behalf of British Railways, represent those of both the Railway Executive and London Transport Executive.

PART I.

Modern tendencies in the construction of structures, particularly of bridges.

A. *General.*

(*a*) Standard train loadings are now adopted generally as the basis on which rail bridges are designed, and a comparative schedule is set out in Appendix I, together with the basis on which dynamic effects, wind loading, braking, etc., are provided for in design.

On some Railways, it is to be noted that the dynamic effects are evaluated according to a formula. On British Railways and South African Railways, the dynamic effect due to hammer blow, is assessed in accordance with the recommendations in the Report of the Bridge Stress Committee, 1928. This does not lend itself to expression in a simple formula, and for routine design purposes, the tabulated values of total

Equivalent Uniformly Distributed Loads (EUDL), are used. The Victorian Railways (Australia) are proposing to evaluate dynamic effects on a similar basis.

In all countries the loading basis for design is covered by Codes and Specifications, which are considered to make adequate provision for future requirements on a long term basis.

The India Railway Board lays down different standards of loading for broad gauge and metre gauge lines, for the classifications, « Heavy Mineral », « Main Line » and « Branch Line » and also for « Light Line ».

London Transport Executive adopts loading standards appropriate to the traffic which will operate over its lines.

(*b*) In most countries, the choice of materials adopted for any particular construction, is governed by total economic considerations, taking account not only of first cost and provision for subsequent renewal, but of the anticipated expenditure on maintenance.

On the Sudan Railways where corrosion is negligible, metal bridges only are used. On the Nizam's State Railways, India, the use of natural stone has predominated wherever construction has lent itself to its adoption, and the Victorian Railways, Australia, make wide use of standard type bridges comprising metal girders and concrete decks.

Elsewhere, at the present time, as renewal of existing bridges comprises a major portion of the new construction in progress, the local site requirements and limitations, particularly in the available construction depth, often severely limit free choice of both materials and form of construction.

Aesthetic considerations are not neglected, particularly where bridges are located in urban areas, and such bridges are designed where possible in a form appropriate to the environment.

(*c*) In all countries the permissible working stresses adopted in design both for metal and concrete bridges are considered to be below the limit for which repeated loading in service will give rise to any fatigue effect in the materials.

In the case of members (e. g. in lattice girders) in which alternations of stress occur under loading conditions, the safeguard against fatigue effect is provided by a requirement that the sum of the greater total stresses together with half the lesser, reversed stress, shall not exceed the permissible stress.

(*d*) Where loading or assembly conditions result in component longitudinal and transverse stresses, in a member, the maximum principal stress is derived and used as the basis for the proportioning of the member concerned.

Although it is realised that in practise uniform distribution of stress scarcely ever occurs in a member designed for axial loading, particularly where welding has been adopted in the fabrication, it is considered to be satisfactory to proportion members on the basis of the average stress.

B. **Underbridges with metal main girders.**

1. *Main girders.*

(*a*) Plate girders are considered to be the most economical and satisfactory form of construction for main girders, both as regards freedom from the development of defects in service, and economy in maintenance, up to spans of about 100-ft.

The limit of span for which they would be adopted in preference to the use of lattice girders is governed by shipping limitations, which vary in different countries. A depth of 12′ 6″ appears to be the limit generally for transport from works to site. The maximum ratio of span to depth adopted by the Railways varies from 10 to 1, as adopted by the India Railway Board to 15 to 1, the limit on the Pennsylvania Railroad Company which Company avoids the use of lattice girders altogether. Elsewhere, lattice girders of the Pratt, or "N" type are preferred, where spans exceed the limit for the use of plate girders.

Bridges carrying double track are gene-

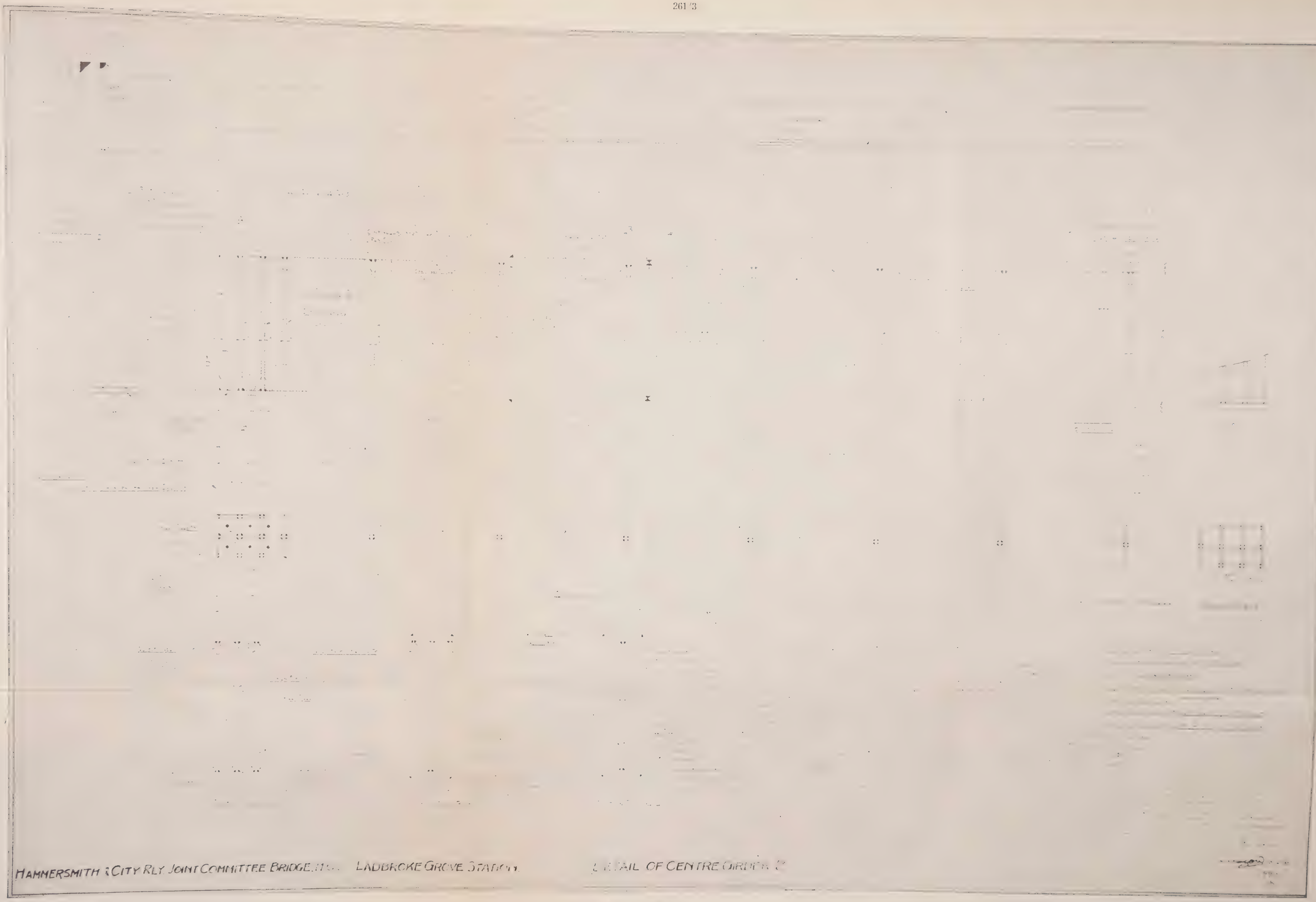

HAMMERSMITH & CITY RLY. JOINT COMMITTEE BRIDGE.
LADBROKE GROVE STATION.
DETAIL OF CENTRE GIRDER

Plate 1.

BRITISH RAILWAYS — NORTH EASTERN REGION

THORPE THEWLES — BRIDGE Nº 18 CASTLE EDEN BNCH. — GENERAL ARRANGEMENT

PLAN Nº 48-YB-2
DATE 8-1-48
SHEETS PER W.S. 480 3/1/8/46

SECTIONAL PLAN ON BB

ELEVATION

ENLARGED CROSS SECTION ON AA

SECTION AT MAIN CROSS GIRDERS

DETAIL OF BUTT WELD IN DECK PLATE OVER RAIL BEARERS

DETAIL OF SMOKE PLATES

SMOKE PLATE CLIPS

WELDING NOTES

All welding to be carried out in accordance with B.S.S. Spec. Nº 538

KEY MAP DIAGRAM

Plate 3.

rally built as double track bridges, as opposed to the use of separate single track bridges, although, where deck type construction is possible the tendency is to keep separate the bridges carrying each track. Some railways consider that where the skew of a bridge is appreciable, it is best to use separate single track bridges if the site conditions permit.

(b) Use of electric welding.

The use of electric welding in the fabrication of plate girders for rail bridges is not yet adopted generally. Of the railway administrations from which reports have been received, bridges have been built with all welded plate girders by the British Railway Executive, London Transport Executive, and the India Railway Board.

Generally, site joints have been riveted, although where the facilities during erection have permitted uninterrupted welding of site joints between floor members, such joints have been welded.

The welded bridge shown on Plates 1 and 2 was constructed for the London Transport Board in 1937, and has been completely successful.

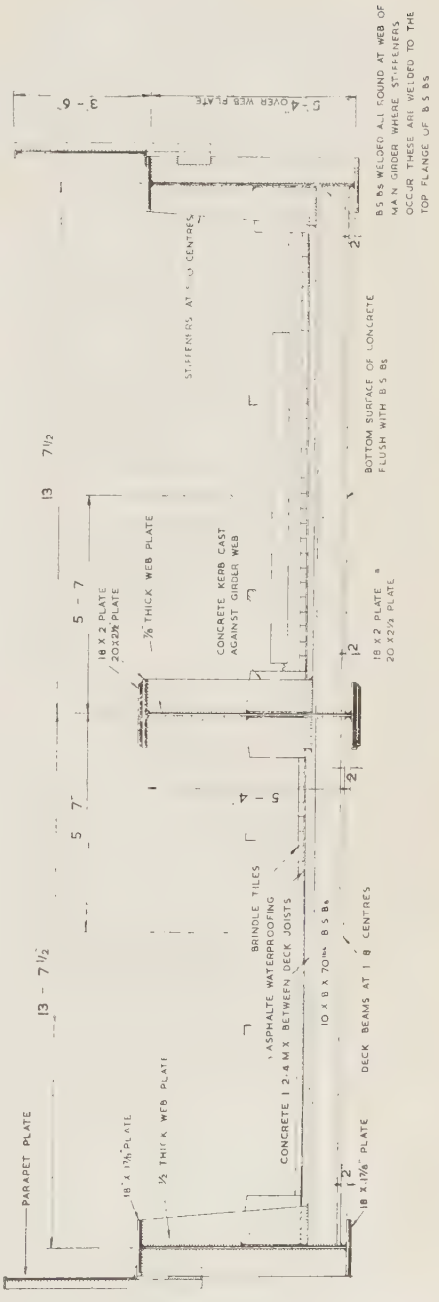
The welded bridge shown on Plate 3 was constructed for the British Railways Executive in 1948. It is being kept under observation, all site joints having been welded.

The welded girders shown on Plate 4 are typical of 24 similar girders for six bridges under construction for the British Railways Executive.

The India Railway Board has recently put into service bridges of about 40-ft. span, comprising welded plate girders, and no difficulty has been experienced.

The use of special rolled sections has so far been avoided by the administrations who have adopted welded construction — simple plates have been used, and welding is generally considered to be satisfactory up to a metal thickness of 3 inches.

The use of angles as Vee connections, T's, cut joists and bulb plates are all under consideration for adoption in welded construction, but there is inadequate experience


PARAPET PLATE
18" X 1/2" PLATE
1/2" THICK WEB PLATE
CONCRETE 12" MIX BETWEEN DECK JOISTS
ASPHALTE WATERPROOFING
BRINDLE TILES
10 X 8 X 70lbs B.S.Bs.
DECK BEAMS AT 1'8" CENTRES
18" X 1/16" PLATE
18 X 2 PLATE
20 X 2/9 PLATE
CONCRETE KERB CAST AGAINST GIRDER WEB
3/8" THICK WEB PLATE
18 X 2 PLATE
20X2/8 PLATE
STIFFENERS AT 4'-0" CENTRES
BOTTOM SURFACE OF CONCRETE FLUSH WITH B.S.Bs
B.S.Bs WELDED ALL ROUND AT WEB OF MAIN GIRDER WHERE STIFFENERS OCCUR THESE ARE WELDED TO THE TOP FLANGE OF B.S.Bs
5'-4" OVER WEB PLATE
3'-6"
13 - 7 1/2
5 - 7
13 7 1/2
5 - 7
4 - 5

Cross section at centre of span.

Plate 2. — London Transport bridge over Ladbroke Grove. All welded steel bridge.

of their use up to the present for firm recommendations to be made.

The India Railway Board alone, reports the adoption of electric welding in the fabrication of lattice girders for rail bridges, of 150 ft. span. Individual members have been built up by welding, but all site joints have been riveted.

(*c*) *Forms of construction.*

Simple or continuous beam types of bridges are generally adopted for the normal range of span.

Where special site requirements justify, other forms of construction are considered, on grounds of economy or fulfilling a condition of limiting construction depth. Recent requirements for such other forms of construction have been limited.

The India Railway Board and the Nizam's State Railway, India, adopt arches wherever site conditions are appropriate.

To fulfil requirements of headroom in relation to span, and available construction depth, the Southern Railway (now British Railway Executive) constructed in 1936 a rail bridge comprising main girders with a main span of 72′ 6″, with continuous short end spans. A pre-determined loading was applied by jacking at the ends of the short end spans and the loading retained at a recorded value by wedging each girder end against a cross-head anchored into the masonry abutment. The general form of construction is shown on Plate 5.

The design is aesthetically satisfactory, and as a form of pre-stressed construction, enabled a comparatively shallow construction depth to be attained, with a deck type construction most appropriate for the site conditions.

(*d*) *Quality of steel for Bridges.*

Mild steel to the national or railway specifications continues to be widely used for the construction of metal bridges as follows :

(i) British Railways, The Railway Executive, London Transport Executive, South African Railways and Harbours to British Standard Specification No. 15 which requires :
Tensile Strength — 28-33 tons per sq. in.
Yield Point (optimal) — 14 3/4-15 1/4 tons per sq. in.
Elongation (Minimum) — 20 % on 8″ gauge length.

(ii) The Pennsylvania Railroad Company to American Society for Testing of Materials Specification A-7.
Which requires :
Tensile Strength — 60 000 lbs. per sq. in. to 72 000 lbs. per sq. in.
Yield Point (Min) — 0.5 of tensile and not less than 33 000 lbs. per sq. in.
Elongation (Minimum) — 22 % on 2″.

(iii) The India Railway Board to India Railway Specification M-5 (very similar to B. S. No. 15).

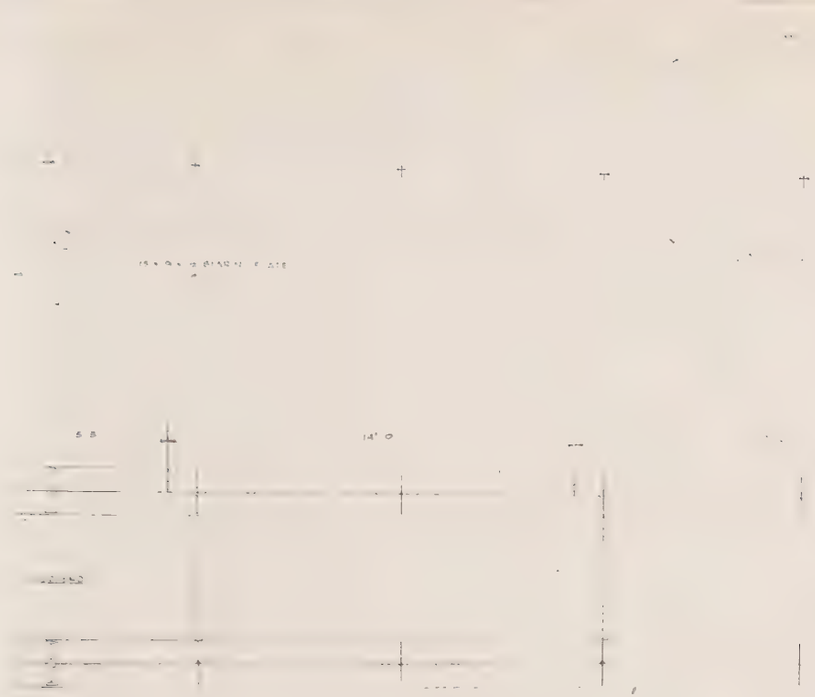
(iv) Sudan Railways; Nizam's Railway, India. To test requirements.

(v) Victorian Railways, Australia to Australian Specification or to British Standard Specification).

The Pennsylvania Railroad Company makes use of a silicon steel in some cases for girders and other members which are not subject to excessive repetitions of loading, as in the case of a half through type bridge of 108-ft. span, carrying four tracks at Crum Lynne, Pa.

The India Railway Board has used high tensile steel to Indian Railway Specification M-23 (ultimate — minimum 35 tons per sq. in.), particularly for top and bottom chord members of long span lattice girders. This has been adopted in the construction of a bridge comprising spans of 350-ft. carrying a double track railway within and a roadway above.

The future trend in the use of special steel for the construction of rail underbridges will be governed by its cost, by the development of quality and techniques whereby welding can be adopted with confidence, and by the future corrosion resisting qualities which become available. Unless a corrosion resisting steel becomes available at economic prices it is envisaged generally that the use of high tensile steel will be limited to



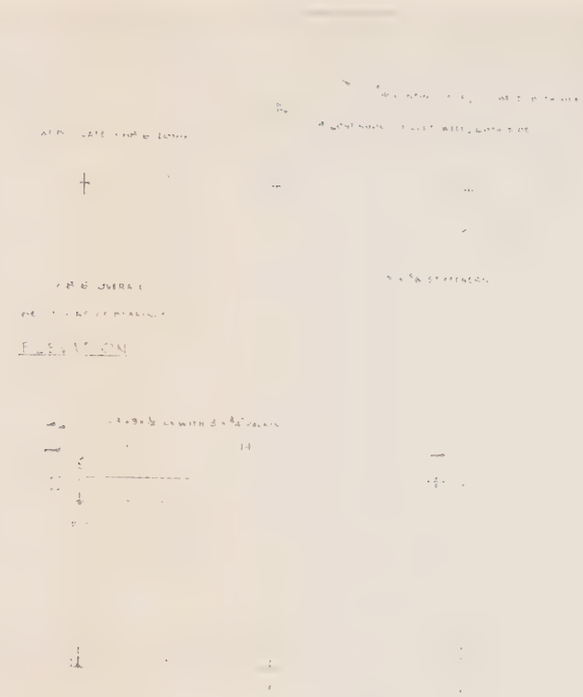


Plate 4.

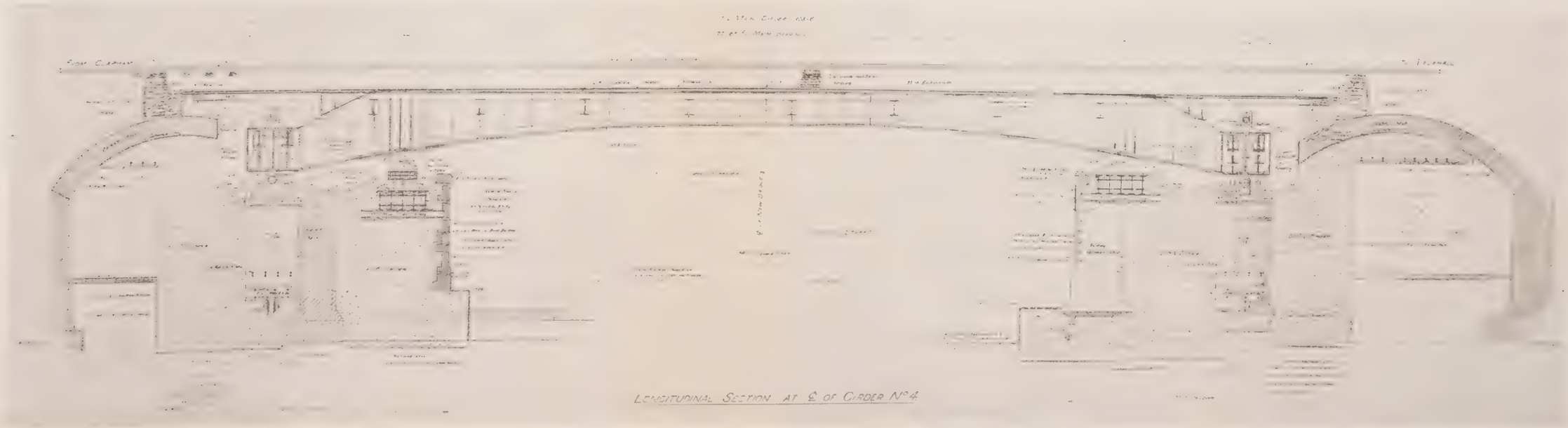


Plate 5. — Reconstruction of Archer street Bridge (S. R. 1935/6).

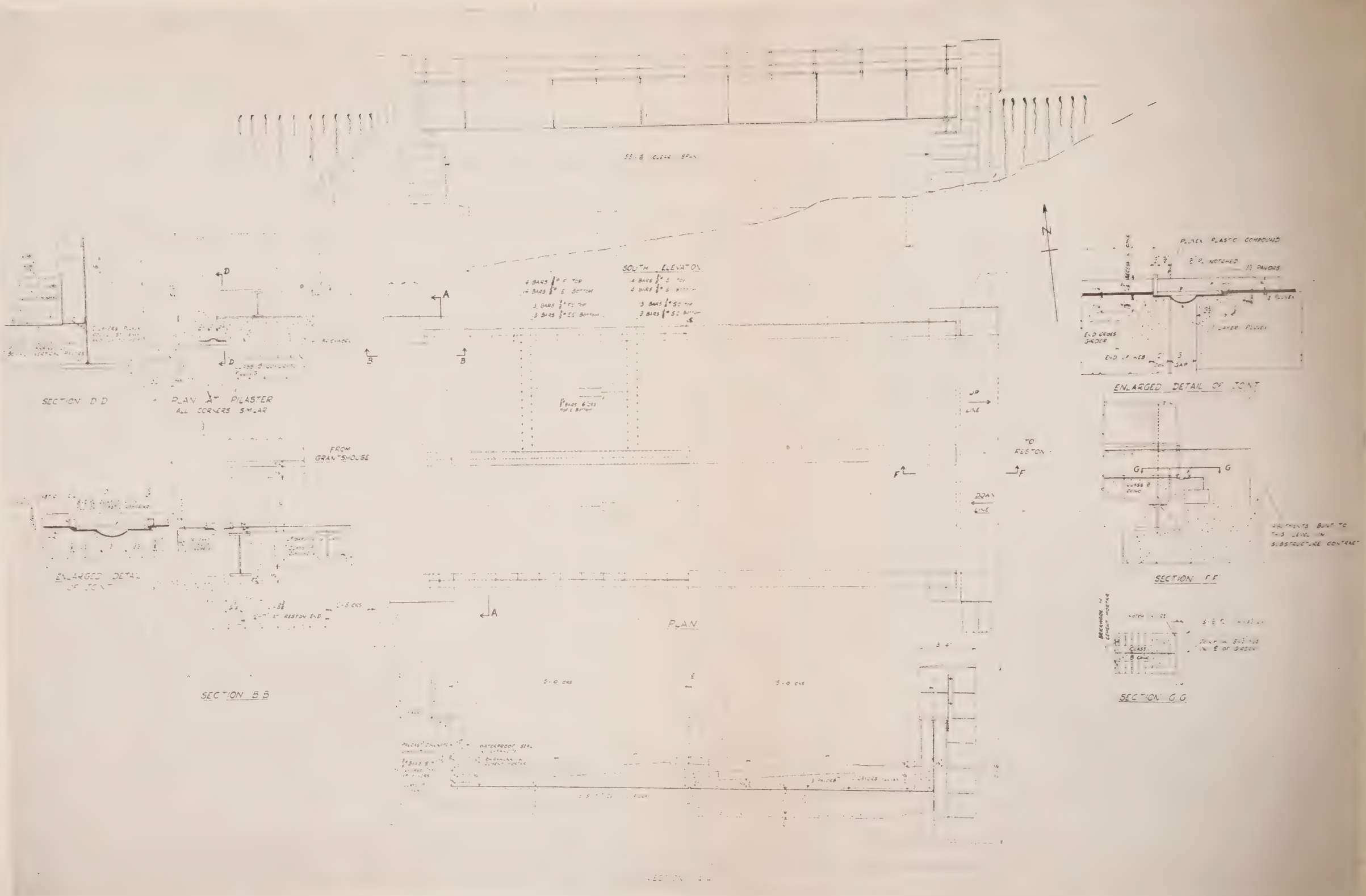

SOUTH ELEVATION
SECTION D D
PLAN AT PILASTER
ALL CORNERS SIMILAR
FROM GRANGEMOUSE
TO RESTON
PLAN
ENLARGED DETAIL OF JOINT
SECTION F F
SECTION B B
SECTION G G
N

Plate 6.

parts of long span bridges where the economy arising from reduction of weight justifies the use of the more expensive steel.

(e) *Light weight alloys.*

None of the administrations which have reported, has made use of light weight alloys for rail bridges.

The India Railway Board in particular envisages considerable scope for the use of such alloys in the construction of underbridges, particularly for long spans.

For medium and long span bridges, the use of light weight alloy in the construction of decks would lead to material saving in the weights of main girders, but the relative cost of light weight alloys in the future will determine the extent to which this practice is developed.

(f) *Composite type bridges.*

Whilst bridges comprising steel main girders and concrete decks are widely used, the Pennsylvania Railroad Company alone, has designed on the basis of the deck comprising a load carrying part of the main girders.

It is reported generally that the circumstances under which site construction would permit the essential requirements of such a construction to be fulfilled are very rare, and in no case has a concrete deck been considered as part of a tension flange, acting compositely with the main girders.

The British Railway Executive makes wide and successful use of decks with steel plate main girders, comprising closely spaced shallow joists cross girders at bottom flange level, completely encased in concrete. (Plate 6). Although no account has hitherto been taken of any assistance given by the deck in carrying part of the flange load, tests have shown that an appreciable tensile load is taken by the deck, and that the neutral axis of the composite bridge is in fact considerably lower than that of the main girders alone.

(g) *Bearings and expansion provision.*

The limiting span for steel main girders, below which plain sliding bearings are provided and above which rocker and roller bearings are provided ranges from 70-ft. on the Victorian Railways, Australia, and the Pennsylvania Railroad Company to about 100-ft. on the India Railway Board. It is becoming a widely adopted practice on British Railways to provide short thick bearing plates to plate girders of spans ranging from about 30-ft. to 70-ft., seated on bed castings or built up steel stools. (See Plate 23.)

The general practice for spans above the sliding bearing limit is to provide rocker bearings at both ends, with rollers at the expansion end. A type design used by the India Railway Board is shown on Plate 7.

Special sliding rail joints are not now generally provided, even on long bridges, other than by the India Railway Board, which adopts scarfed or mitred rail joints (See Plate 8) located over piers, where intermediate rail joints are welded.

2. *Bridge decks entirely of metal construction.*

(a) *Track support.*

All administrations consider that where it is not possible to provide sleepered track on ballast, over the metal deck of a bridge, the most satisfactory method is to use timber cross bearers, sleepers, or ties, to carry the rails. Whilst in some countries in the past, longitudinal timbers have been provided to carry the rails, it is the experience generally that for most cases this is not the better method. True line and level of the track and timber maintenance can be carried out more readily, when the rails are carried on cross timbers. The results of derailments on a bridge are also thought to be less serious.

It is doubtful if any method, completely satisfactory for application to all cases has yet been found to overcome the track maintenance difficulty at the ends of bridges over which the track is carried on timber direct on to a metal deck, particularly in the case of open bridges. On British Railways,

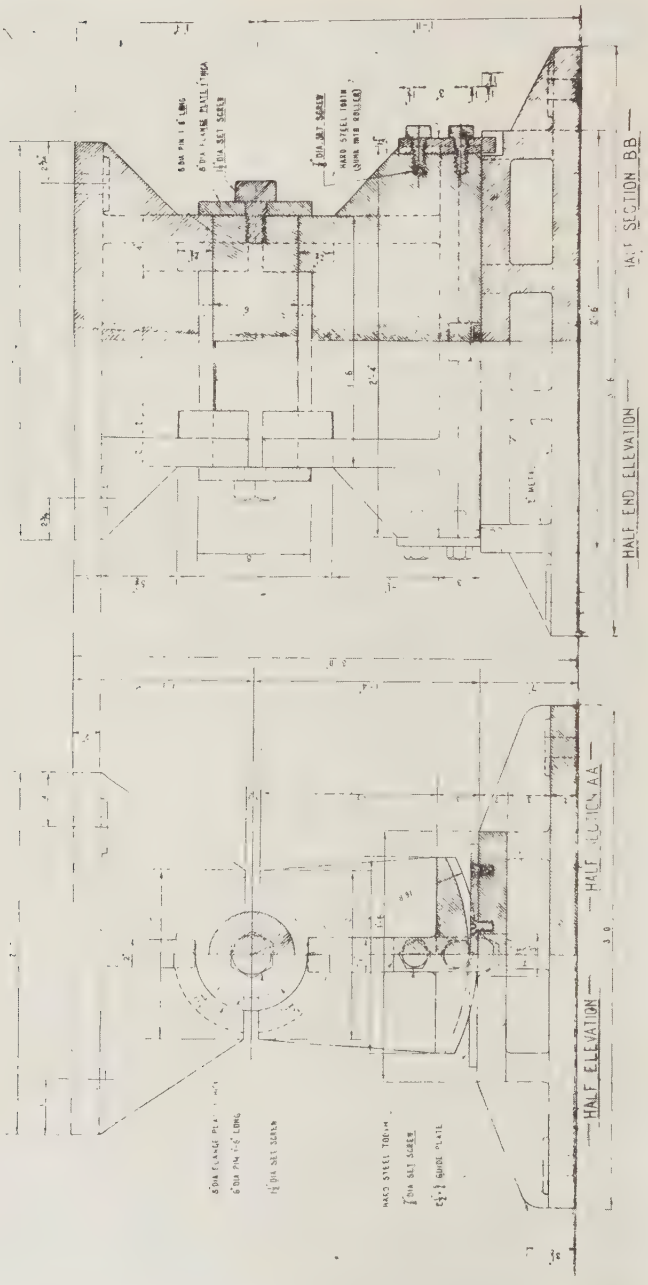


Plate 7. — Bearings-Expansion end.

longitudinal wheel timbers have been extended beyond the ends of the bridge, supported from the ground on pads arranged to graduate the stiffness of support from that of the hard bridge to that of the normal track on the approach formation. The India Railway Board has adopted similar methods in some cases.

be simple and economical both in fabrication and assembly. But it is generally considered that the rigidity given by fitting railbearers into cross-girders, is of sufficient value to justify its adoption in most cases, even where the construction depth available would have permitted the alternative form of construction. Provided that fitted con-

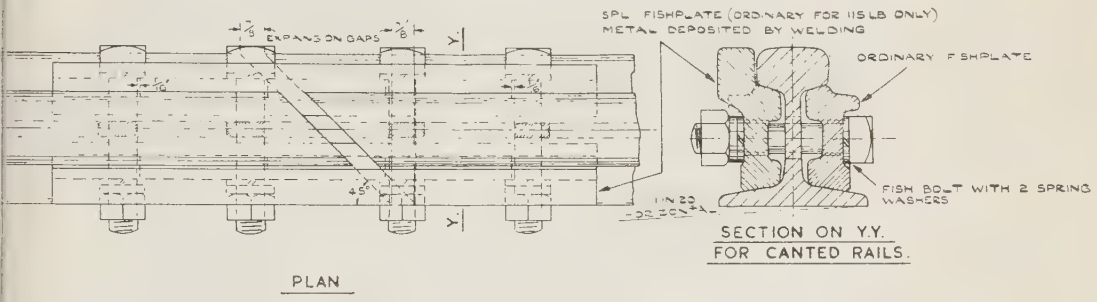
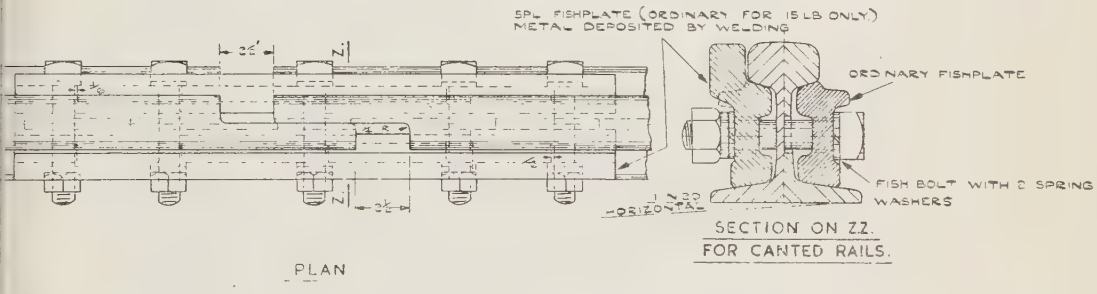

EXPANSION GAPS
SPL FISHPLATE (ORDINARY FOR 115 LB ONLY) METAL DEPOSITED BY WELDING
ORDINARY FISHPLATE
FISH BOLT WITH 2 SPRING WASHERS
1 IN 20 FOR CANT
SECTION ON Y.Y. FOR CANTED RAILS.
PLAN

Plate girder bridges up to 100 ft. clear spans.


SPL FISHPLATE (ORDINARY FOR 15 LB ONLY) METAL DEPOSITED BY WELDING
ORDINARY FISHPLATE
FISH BOLT WITH 2 SPRING WASHERS
1 IN 20 HORIZONTAL
SECTION ON Z.Z. FOR CANTED RAILS.
PLAN

For girder bridges up to 350 ft. clear spans.

Plate 8. — India Railways. Rail expansion joints.

The Victorian Railways, Australia, avoid the use of metal decks entirely, and on British Railways, and the South African Railways and Harbours, provision is made in new construction for ballasted tracks wherever possible.

(b) *Deck assembly.*

The construction whereby long continuous railbearers are placed on top of cross girders is considered by administrations to

nections are well designed less trouble from the development of loose rivets is anticipated.

Future developments in the use of all welded connections may modify the present view, as greater rigidity in the connections to cross-girders can be more readily provided than in riveted construction.

A construction adopted in the case of a bridge carrying slow speed traffic, by the Southern Railway (now within the British Railways Executive) is shown on Plate 9.

This has been quite free from any undesirable developments during the twenty years since it was constructed.

Up to the present there has been very limited adoption of electrically welded connections between railbearers and cross-girders, and cross-girders and main girders. Some administrations prohibit the practice. The British Railway Executive, and the London Transport Executive have constructed bridges in recent years with a completely welded assembly. It is only permitted where assembly conditions enable complete connections to be welded without interruption, and where there is freedom for the contractions to be accommodated by relative movements of the units of the assembly, The few works carried out to date have been quite successful. Care has been taken in design to provide for the transfer of the fixing moments which must accompany the adoption of electrically welded connections (See Plate 10).

The India Railway Board, whilst generally adopting riveted connections has welded top and bottom strap plates at fitted railbearer to cross-girder connections.

(c) *Dynamic effects.*

The Pennsylvania Railroad Company reports that fair agreement has been found between the dynamic increments of stresses recorded in floor members under live loading, and the values derived from the application of the formula adopted by them.

Recordings made on British Railways, the India Railway Board, and the South African Railways and Harbours have indicated that the actual dynamic increment can be appreciably different from the value as derived from the application of the various formulae used for design purposes.

Generally recorded values are the lower.

It is realised that, particularly in the case of recordings on floor members, the dynamic increment is inherently subject to a wide range of variation as applied to a particular unit of a floor, and that the local condition of the track re-acts on the magnitude of the dynamic effect of the live load. The rapid stress fluctuations which take place in floor members under live loading at speed give rise to recording difficulties. The South African Railways and Harbours propose to make full investigation into this problem, using S. R. 4 strain gauges.

Hitherto, no administration has investigated the effect of varying track irregularities on the dynamic increment of live loading. The Report of the Bridge Stress Committee to the Committee of the British Privy Council for Scientific and Industrial Research, in 1928, recommended that the dynamic increment due to rail joints, track irregularities and wheel irregularities would be covered by the effect of a concentrated force per track of $N^2/6$ tons, where N is the speed in revolutions per second of the main driving wheels of a locomotive.

Tests carried out by the India Railway Board have led to conclusions summarised in Table 1 below :

TABLE 1.

Spans ft.	Percentages in terms of M. L. Standard loads			
	Hammer blow	Rail joint	Lurching	Total impact
10	25	43	40	108
15	25	30	40	95
20	25	24	40	89
30	23	18	40	81
40	20	14	35	69
50	20	12.5	30	62.5
60	20	11	30	61

BRITISH RAILWAYS – NORTH EASTERN REGION

THORPE THEWLES – BRIDGE No18 CASTLE EDEN BRANCH – DETAILS OF CROSS GIRDERS ETC.

DRAWN BY

SCALE

DETAIL OF MAIN CROSS GIRDER. 4 REQUIRED THUS.

CROSS GIRDER ENDS TO BE SQUARE

SECTION AA

SECTION BB

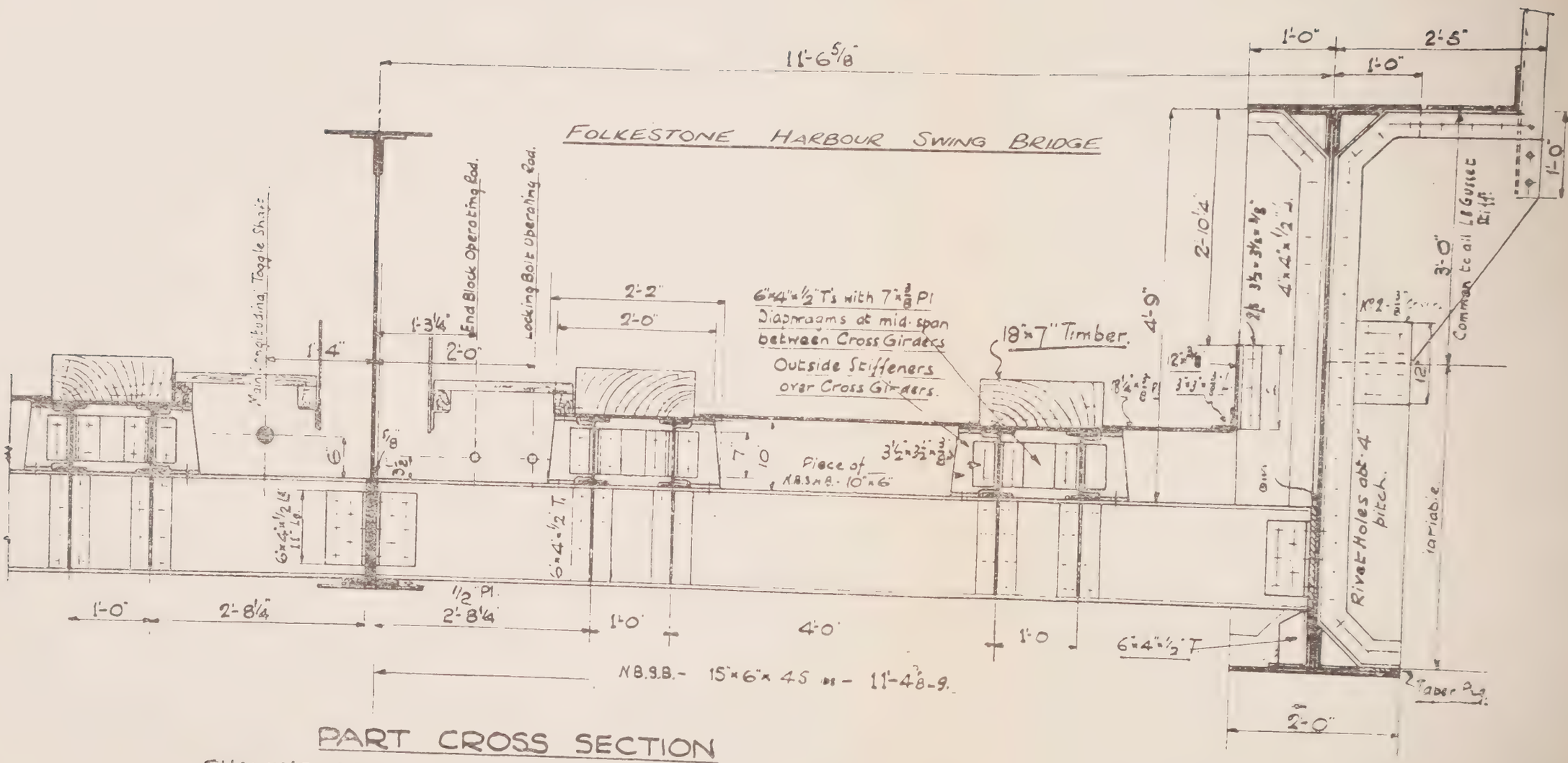
SECTION CC

SKEW END CROSS GIRDER. 2 REQUIRED THUS.

END VIEW

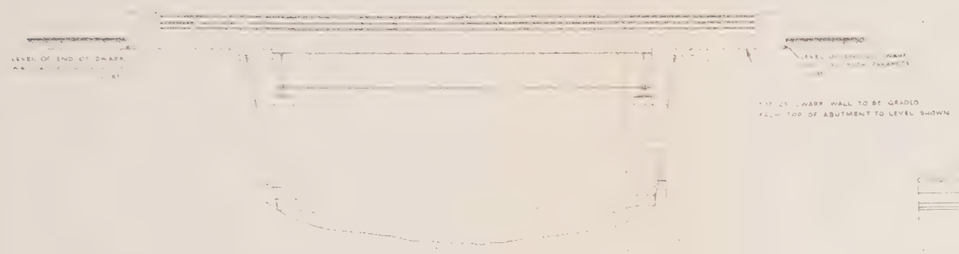
CROSS GIRDER 2 REQUIRED THUS.

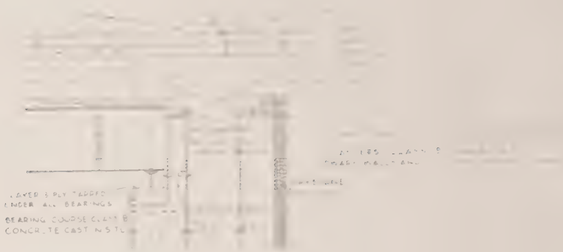
Plate 9.

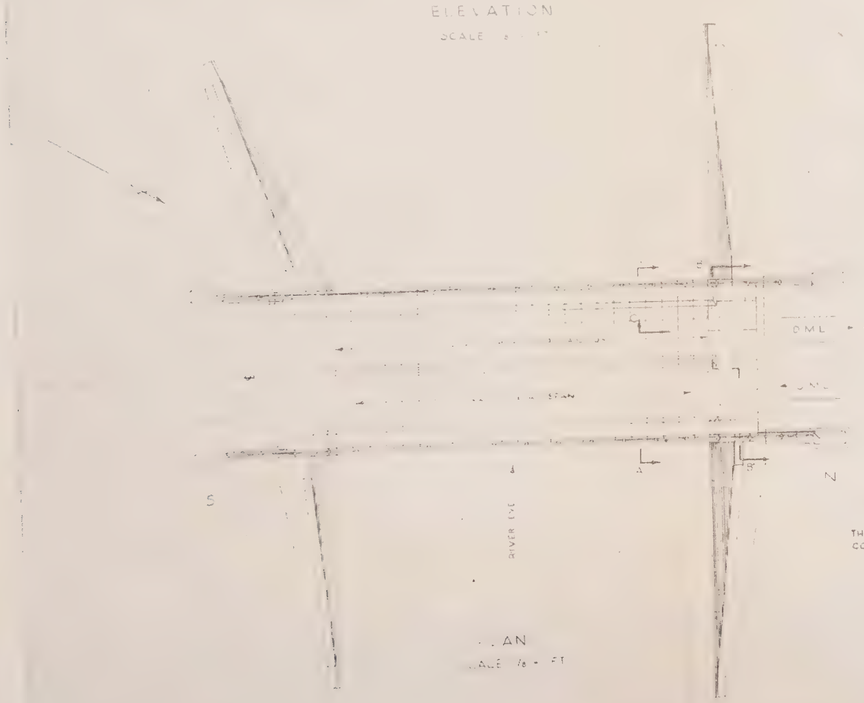


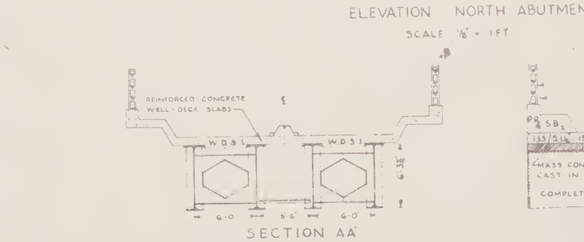
PART CROSS SECTION
SHOWING ORDINARY CROSS-GIRDERS & RAILBEARERS

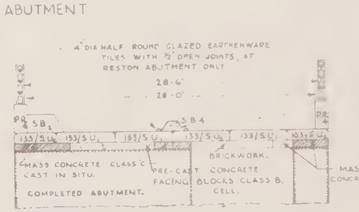
Plate 10.



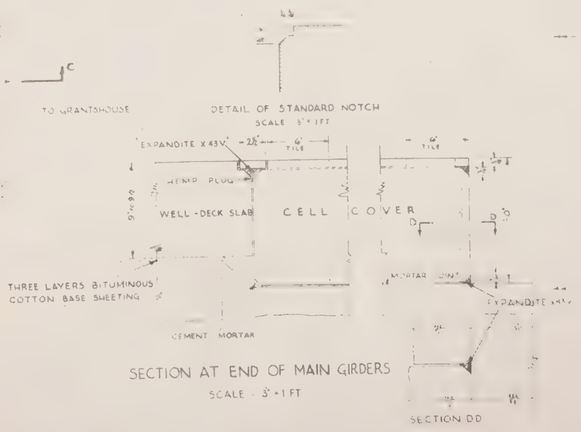



ELEVATION
SCALE
PLAN
SCALE 1/8" = 1FT
RIVER EXE
DML
TO GRANTSHOUSE


ELEVATION NORTH ABUTMENT
SCALE 1/8" = 1FT
REINFORCED CONCRETE WELL-DECK SLABS
W.D.S.1
W.D.S.1
6'-0"
5'-6"
6'-0"
SECTION AA
SCALE 1/4" = 1FT


4" DIA HALF ROUND GLAZED EARTHENWARE TILES WITH ½" OPEN JOINTS AT RESTON ABUTMENT ONLY
28'-6"
28'-0"
MASS CONCRETE CLASS C CAST IN SITU.
COMPLETED ABUTMENT.
PRE-CAST CONCRETE FACING.
BRICKWORK BLOCKS CLASS B. CELL.
MASS CONCRETE.
SECTION BB
SCALE 1/4" = 1FT

60° C APPROX
HALF PLAN
DETAILS OF WATERPROOF JOINTS
SCALE ¼" = 1FT


DETAIL OF STANDARD NOTCH
SCALE 3" = 1FT
EXPANDITE X 43 W
TILE
TILE
LEAD PLUG
WELL-DECK SLAB
CELL COVER
THREE LAYERS BITUMINOUS COTTON BASE SHEETING
MORTAR JOINT
EXPANDITE
CEMENT MORTAR
SECTION AT END OF MAIN GIRDERS
SCALE 3" = 1FT
SECTION DD

66 0% BEARINGS
DIMENSIONED PLAN OF ABUTMENTS
SCALE ¼" = 1FT

Plate 11.

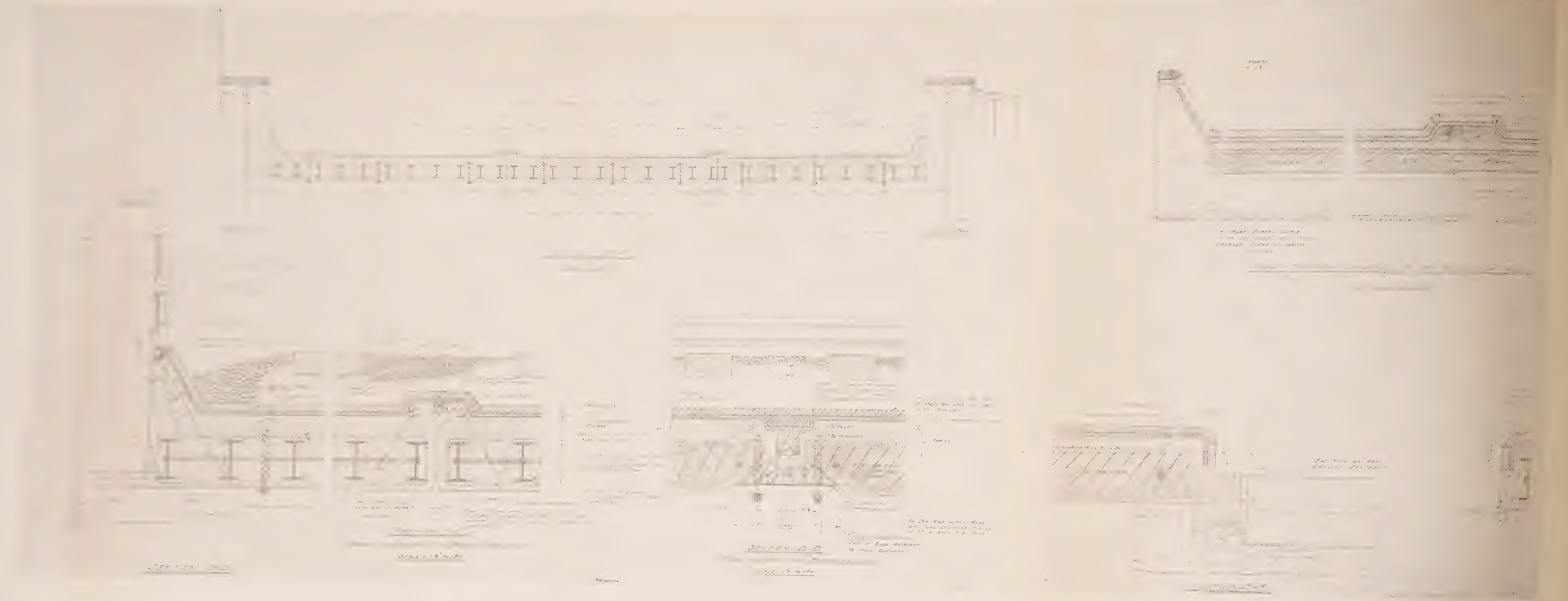


Plate 12.

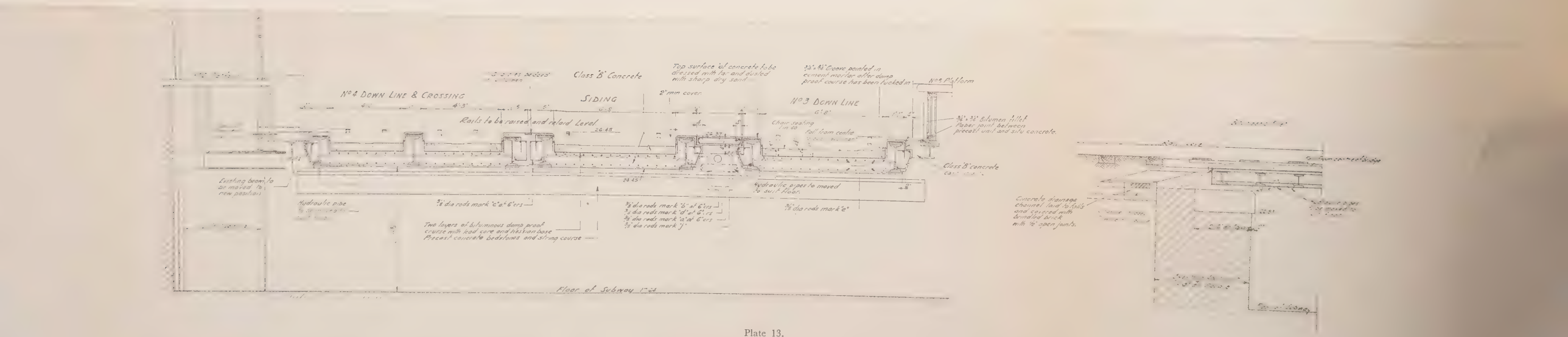

No 4 DOWN LINE & CROSSING
SIDING
No 3 DOWN LINE
Class 'B' Concrete
Top surface of concrete tube dressed with tar and dusted with sharp dry sand
3/8" x 3/8" Cove pointed in cement mortar after damp proof course has been tucked in
No 5 Platform
Rails to be raised and relaid Level
Chair seating
Foil from centre
3/8" x 3/8" Bitumen filled Paper joint between precast unit and situ concrete
Class 'B' concrete
Existing beam to be moved to new position
Hydraulic pipe
Hydraulic pipes to be moved to suit Floor
Two layers of bituminous damp proof course with lead core and thixian base
Precast concrete bedstones and string course
Concrete drainage channel laid to falls and covered with brindled brick with 1/2" open joints.
Floor of Subway

Plate 13.

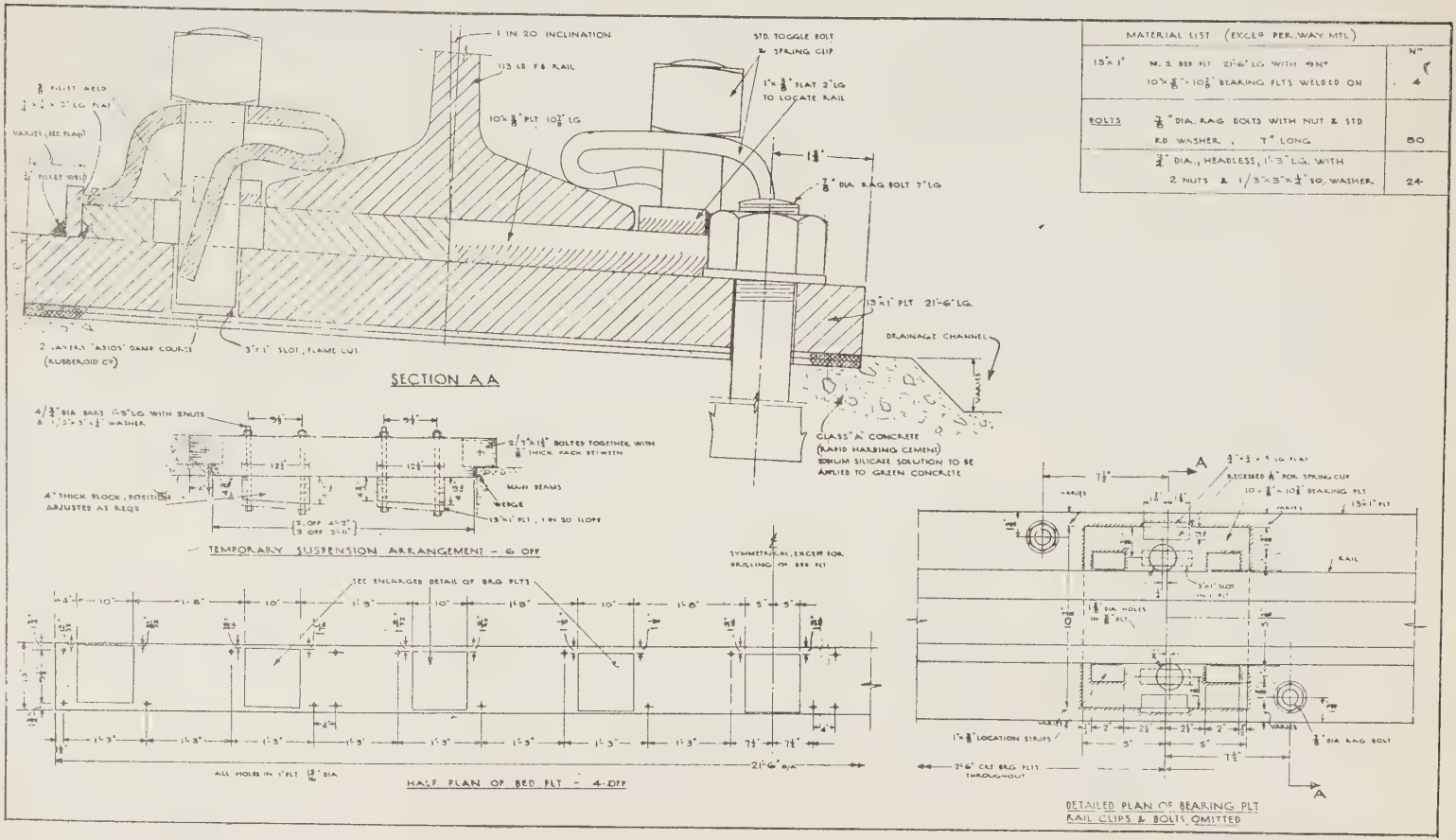

MATERIAL LIST (EXCLG PER WAY MTL)
13"x1" M.S. BED PLT 21'-6" LG. WITH 9 No 10"x⅞"-10½" BEARING PLTS WELDED ON — No 4
BOLTS ⅞" DIA. RAG BOLTS WITH NUT & STD R.D WASHER, 7" LONG — 50
¾" DIA., HEADLESS, 1'-3" LG. WITH 2 NUTS & 1/3"x3"x¾" SQ. WASHER — 24
1 IN 20 INCLINATION
STD TOGGLE BOLT & SPRING CLIP
113 LB F.B RAIL
1"x⅜" FLAT 2" LG TO LOCATE RAIL
10½"x⅞" PLT 10½" LG
⅜" FILLET WELD
½"x4½"x3" LG FLAT
VARIES (SEE PLAN)
⅜" FILLET WELD
1½"
⅞" DIA RAG BOLT 7" LG
13"x1" PLT 21'-6" LG.
2 LAYERS "ASIOS" DAMP COURSE (RUBBEROID CO)
3"x1" SLOT, FLAME CUT
DRAINAGE CHANNEL
VARIES
SECTION A A
CLASS "A" CONCRETE (RAPID HARDING CEMENT) SODIUM SILICATE SOLUTION TO BE APPLIED TO GREEN CONCRETE
4/¾" DIA BARS 1'-3" LG WITH 2 NUTS & 1/3"x3"x¾" WASHER
2/7"x1½" BOLTED TOGETHER WITH ⅜" THICK PACK BETWEEN
4" THICK BLOCK, POSITION ADJUSTED AS REQD
MAIN BEAMS
WEDGE
13"x1" PLT, 1 IN 20 SLOPE
(3 OFF 4'-2")
(3 OFF 3'-11")
TEMPORARY SUSPENSION ARRANGEMENT - 6 OFF
SYMMETRICAL EXCEPT FOR DRILLING ON BED PLT
SEE ENLARGED DETAIL OF BRG PLTS
ALL HOLES IN 1" PLT 13/16" DIA
HALF PLAN OF BED PLT - 4 OFF
⅜"x4½"x1'-4" LG PLAT
RECESSED ⅜" FOR SPRING CLIP
10"x⅞"x10½" BEARING PLT
13"x1" PLT
RAIL
1⅛" DIA HOLES IN ⅜" PLT
1"x⅜" LOCATION STRIPS
⅞" DIA RAG BOLT
21'-6" CKD BRG PLTS THROUGHOUT
DETAILED PLAN OF BEARING PLT
RAIL CLIPS & BOLTS OMITTED

Plate 13A. — British Railways (L. M. Region) Stour Valley bridge No. 1. Method of fixing rail.

The practice of using welded rail joints where rail joints occur on bridges is not general. It is done on British Railways, the Pennsylvania Railroad and by the India Railway Board when the conditions justify, and rails have been welded into lengths up to about 300-ft. on bridges. Welding of rail joints on bridges has been done on British Railways particularly where the tracks carry an intensive service of multiple-unit electric passenger trains.

(d) *Guard and check rails.*

There is wide variation in the pratice of administrations in providing guard rails or check rails on bridges to safeguard against the effects of derailments.

The Pennsylvania Railroad Company provides guard rails on all drawbridges, through bridges, half through bridges, and on deck bridges of span exceeding 40-ft., and on all deck bridges carrying curved track.

Other administrations take account of the length of the bridge or viaduct, the construction of the bridge in relation to the consequences of derailment, and the curvature of the approach track.

The use of check rails or guard rails, with re-railing ramps in some cases appears to be generally to safeguard against the case of the vehicle which has derailed before it has reached the bridge, and such provisions have been found effective in practice.

3. *Concrete decks to metal bridges.*

(*a*) *General.*

Complete divergence of practice is reported on the use of reinforced concrete decks with metal main girders for rail bridges.

British Railways, the Pennsylvania Railroad Company and the Victorian Railways, Australia, use reinforced concrete decks, particularly in the construction of new deck type underbridges, whereas the India Railway Board, the Nizam's State Railway, the South African Railways and Harbours and the Sudan Railways, do not.

The main advantages from the use of concrete decks are stated to be their suitability for providing ballasted tracks, their ease of erection, the elimination of fire risk associated with the use of timber, and the elimination of noise under traffic.

The Victorian Railways, Australia, adopts a type of concrete deck embodying rails as a standard form of construction.

Recent constructions by the British Railway Executive, have made use of reinforced concrete decks as shown on Plate 11.

All administrations which now use concrete decks propose to continue their practice. The South African Railways and Harbours administration considers the weight and cost does not compete on their system with their practice of providing steel trough decks.

It is the practice on the railways which use reinforced concrete decks on metal main girders, to permit direct contact between the deck concrete and the steelwork, although most recent practice on British Railways in the case of deck type girder bridges is to bed the slabs on hessian based bituminous sheeting, laid on the girder flanges.

Where the deck is at or near the bottom flanges of main girders, it is very difficult to secure a permanent, absolutely reliable seal between the concrete and the steelwork. The Pennsylvania Railroad Company generally provides a vee groove between the top of the junction between the concrete and the metal, to be filled with waterproofing mastic.

It is general practice on British Railways, where erection facilities permit, to carry the concrete up the web, at an angle if possible, or provide a brickwork infill, and waterproof the surface and seal against the steelwork with layers of hessian based bituminous sheeting and bitumen compound.

A type of flexible joint between pre-cast concrete deck slabs, where joints had to be arranged over cross-girders, as adopted by the British Railway Executive, is shown in Plate 12.

No administration has yet adopted either

deck units of pre-stressed concrete, or concrete decks pre-stressed both longitudinally and laterally.

As concrete decks are usually associated with the provision of ballasted tracks, no special arrangements are considered to be necessary at the ends of bridges, such as are sometimes made at the ends of bridges on which the track is carried on timber, resting direct on the deck.

All administrations using concrete decks with ballasted tracks agree on a desirable depth of ballast of 12-inches, but limited construction depth in many cases, leads to the acceptance of minima as shallow as 3″ by the Victorian Railways, Australia, and 4″ by British Railways. Where a depth approaching the desirable can be provided, the standard size of track ballast is used, but where the very limited depths as indicated above are permitted it is the practice to use ballast not exceding 1″ grading.

(b) Waterproofing.

Waterproofing of concrete bridge decks is only carried out in special cases by the Victorian Railways, Australia, and in these cases, asphalte, from 3/4″ to 1″ is used.

British Railways and the Pennsylvania Railroad Company waterproof concrete bridge decks, particularly where it is desirable to prevent water dripping on to public roadways below, and on to the steelwork of main girders. Protection for the latter purpose is considered to be most important, to avoid corrosion at inaccessible places.

Both administrations use as the waterproofing medium, layers of bituminous sheeting with a woven hessian base, bonded with bitumen compound, laid hot. The Pennsylvania Railroad Company protects this with a 1 /2″ thick layer of bituminous concrete, and British Railways protect with quarry tiles (about 1 ″thick), or Brindle Paving (about 1 1/2″ thick), bedded in a plastic bitumen compound on top of the waterproofing layers.

Special requirements are laid down as to the provision of laps at joints in the sheeting (not less than 3″), joints in each layer to break joint with those of lower layers, and relating to the provision of ample cover where horizontal surfaces meet vertical or inclined surfaces.

This type of waterproofing, of a flexible nature, has been found satisfactory in service, provided that it is protected from the damaging effects of sharp stones and tools used for maintenance of the track.

(c) Check rails, etc.

No different practice is reported in respect of the provision of check and guard rails over bridges with concrete decks, than is followed for bridges generally, as reported above, except in so far as general practice is affected by the fact that tracks are ballasted.

It is considered to be less important to weld rail joints on bridges having concrete decks with ballasted tracks than on bridges with metal decks with rails carried direct on timbers.

Rail joints on bridges with concrete decks and ballasted tracks are considered to give rise to less dynamic effects from the live load than in the case of bridges with metal decks, but no recorded results are available to the reporting administrations on which firm recommendations thereon can be based.

Administrations have avoided laying the track direct on to the concrete deck of this type of underbridge, with neither ballast bed nor timbers, although it has been done in one difficult case by British Railways. (See Plates 13 and 13A). It is possible that more recent developments in the use of a layer of bonded rubber, providing cushioning between rails and baseplates or sleepers, if found successful in service, may provide the basis for a construction in the future whereby the track can be laid direct on to concrete bridge decks without fear of undesirable developments.

4. *General observations.*

Present directions of development are not leading to material changes in the

general form of construction of metal underbridges, except pershaps in the wider use on some Railways of concrete decks with ballasted tracks. An increase in the ment of such steels, so far as concerns their cost, their resistence to corrosion, compared with mild steel, and their suitability for fabrication by welding.

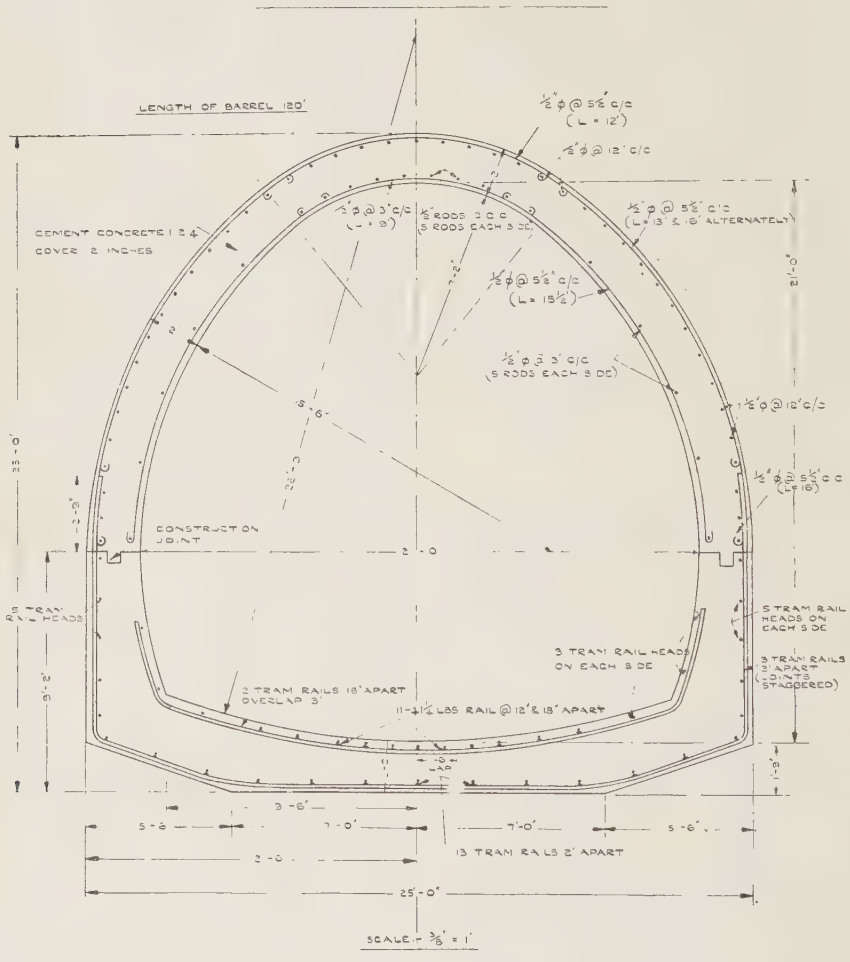

LENGTH OF BARREL 120'
CEMENT CONCRETE 1 2 4
COVER 2 INCHES
CONSTRUCTION JOINT
3 TRAM RAILS 18" APART OVERLAP 3'
11-41½ LBS RAIL @ 12' & 18" APART
3 TRAM RAIL HEADS ON EACH 3 DE
5 TRAM RAIL HEADS ON EACH 3 DE
3 TRAM RAILS 3' APART (JOINTS STAGGERED)
13 TRAM RAILS 2' APART
SCALE - 3/8" = 1'

Plate 14. — Nizam's State Railway. R. C. C. culvert.

adoption of fabrication by welding is envisaged by those administrations which have already adopted welding in the construction of bridges.

The use of special steels is likely to increase, but will depend on the development of such steels, so far as concerns their cost, their resistence to corrosion, compared with mild steel, and their suitability for fabrication by welding.

The development of light weight alloys is being closely followed with intent to use for bridge construction when economically justified.

The India Railway Board is developing designs making use of light weight alloys.

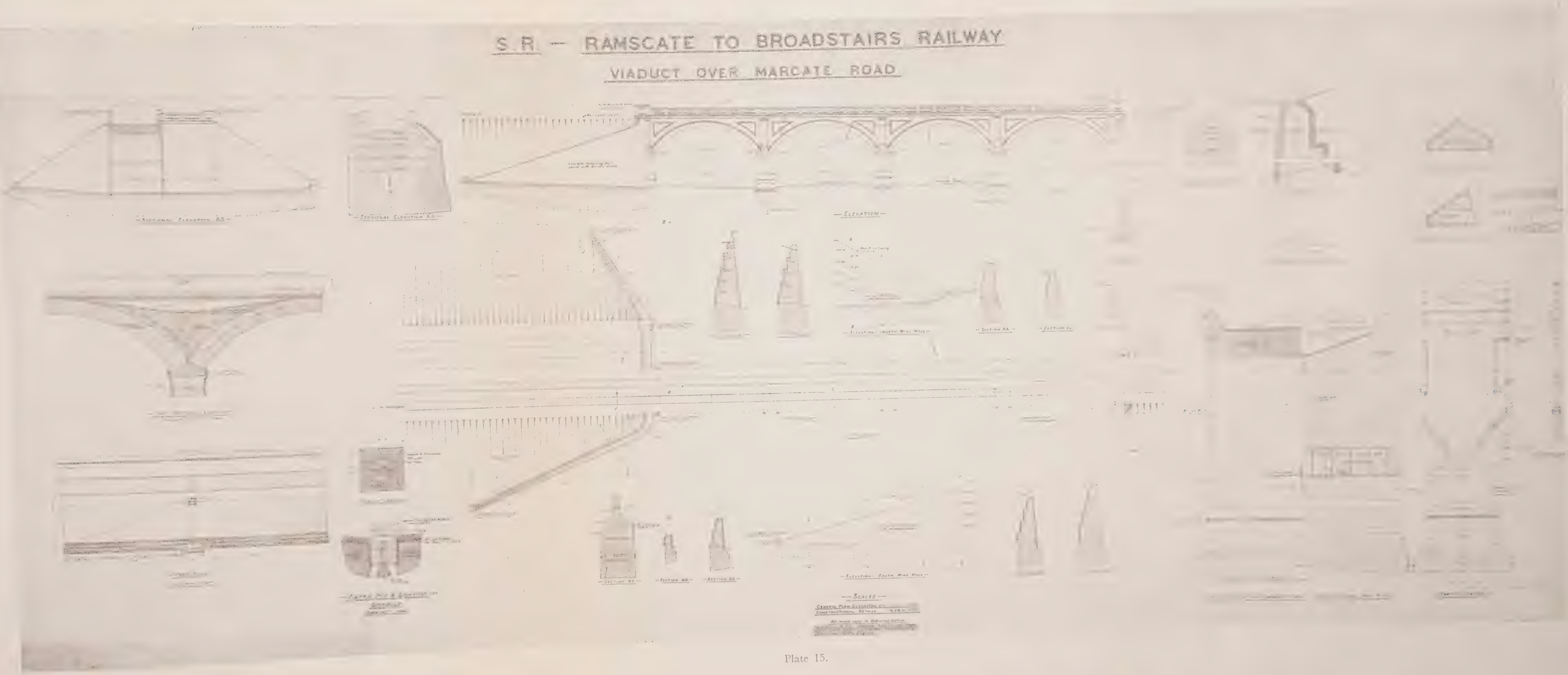

S.R. — RAMSCATE TO BROADSTAIRS RAILWAY
VIADUCT OVER MARGATE ROAD
— Elevation —
— Scales —

Plate 15.

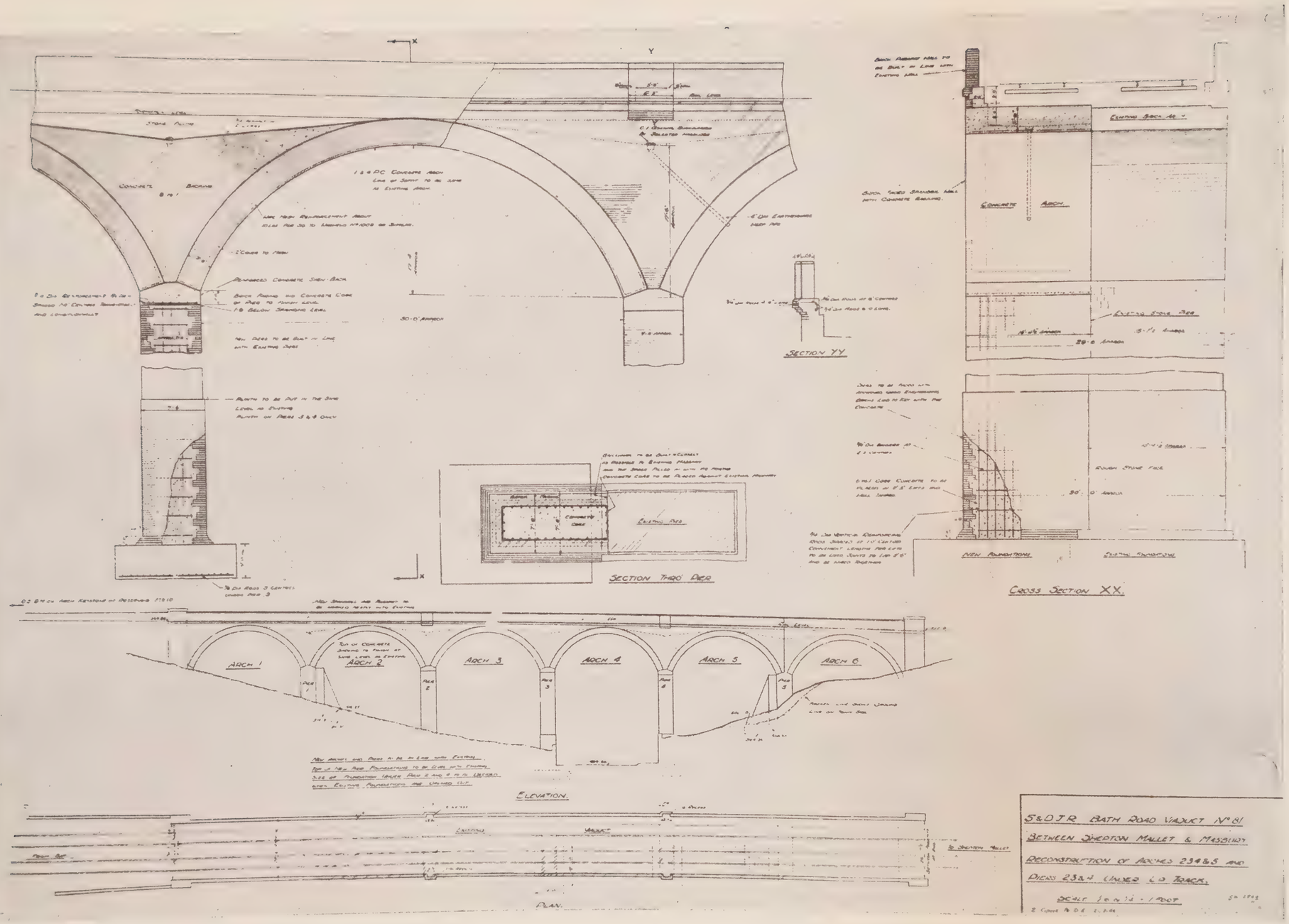

SECTION YY
SECTION THRO' PIER
CROSS SECTION XX.
ELEVATION.
PLAN.
ARCH 1
ARCH 2
ARCH 3
ARCH 4
ARCH 5
ARCH 6
5&DJR BATH ROAD VIADUCT Nº 81
BETWEEN SHEPTON MALLET & MASBURY
RECONSTRUCTION OF ARCHES 2 TO 5 AND
PIERS 2 TO 4 UNDER L.D. TRACK.
SCALE 10 0 10 20 30 40 50 60 70 80 90 100 FEET
1 INCH = 10 FEET
SCALE 1 INCH = 1 FOOT

Plate 16.

C. *Masonry underbridges.*

(*a*) *Design.*

The extent to which masonry arch underbridges are used at the present time varies widely on different railways.

The Victorian Railways, Australia, has not built any masonry bridges for very many years, whereas the Nizam's State Railways, India, constructs masonry arches wherever possible and has standard type designs for openings up to 30-ft. Other administrations use masonry arches in preference to metal or concrete bridges where, for the particular circumstances, such a form of construction is most suitable and economical.

The India Railway Board have developed standard types of construction for masonry arches of spans up to 30-ft., and the South African Railways and Harbours, of spans up to 40-ft.

It is usual practice for arches to span openings up to about 30 to be proportioned in the first place from experience and empirical rules based on the many masonry arches of similar span which have adequately carried increasing weight of traffic for up to 100 years.

The provisional design is then checked by most administrations, either graphically or by analysis based on elastic theory.

It is considered generally that special consideration should be given to shape and to varying the thickness of the masonry arch, for spans exceeding 30-ft.

Although numerous long span masonry arch bridges exist, which were built so far as is known, without any special provision to ensure that they would behave in a predetermined manner, it is considered that in the construction of such spans, in the future, steps should be taken either by the provision of permanent hinges, or by taking special load determining measures during construction, to safeguard that behaviour in service will conform with the basis adopted for design.

The India Railway Board recommends that hinges should be provided at the abutments to safeguard against the effect of slight unequal settlement of abutments.

(*b*) *Construction.*

The choice of material for the construction of masonry arch bridges of the more usual spans varies widely on the systems from which reports have been received, being governed by the availability or otherwise of natural stone, engineering quality bricks, and concreting materials, and whether the number of similar arches to be constructed justifies the provision of the special forms required for building in concrete.

Except where granite block work is used in the construction of such arch spans, as on the Nizam's State Railway, India, it is general practice to provide bond through the arch thickness, by the use of a proportion of headers in masonry and brick construction and the use of reinforcement in concrete construction.

Generally, special treatment of the exposed surfaces of masonry arch bridges is avoided, unless aesthetic reasons in a particular case are considered of sufficient importance. Where construction is in concrete, careful attention is given to the formwork to result in a clean surface, and after stripping, the exposed surfaces are generally rubbed down with carborundum bricks.

Facing with block masonry is only adopted by the Pennsylvania Railroad Co. and the India Railway Board, on exposed surfaces, in special cases, and they report that no trouble has been experienced where this has been done, arising from any difference which there may be between the elastic moduli of the facing and the mass masonry. No data is available as to the magnitude of any such difference in elastic moduli.

The sequence of construction is generally carefully planned and followed, to reduce any affects or shrinkage and creep in the masonry.

(*c*) *Examples of more recent constructions.*

The Nizam's State Railway, India,

reports the use of reinforced concrete for the construction of culverts in recent years, of the form shown on Plate 14.

British Railways report on new viaducts constructed in recent years using brickwork and concrete as follow :

(i) A four span viaduct, as shown on Plate 15 having clear openings of 65′ 0″ built with brickwork in cement mortar, having a thickness of arch of 4′ 6″ at the crown, and 6′ 0″ at the springings, of circular arc form with a rise of 17′ 6″. Reinforced concrete skewbacks were provided on the piers and abutments to take the arch springings. Weak concrete backing was used and the asphalte waterproofing layers were laid on the backing to fall to outlets at the piers and abutments.

(ii) The reconstruction of four spans of a six span arch viaduct as shown on Plate 16, carrying one track of a double line following complete collapse of a masonry faced pier due to weakness arising from percolation of water into the interior of the pier.
Piers were reconstructed in brick faced concrete, the concrete core being reinforced with steel bars. The arches, of 50-ft. clear opening and about 17′ 4″ rise were built in mass concrete with a reinforcing mesh located close to the inner surface. Backing was of weak concrete with asphalte waterproofing laid to fall to the piers. The new construction was not bonded to the old work.

The South African Railways and Harbours report that the construction of Klip-rivier Bridge is in hand, in mass concrete construction, comprising eight 40-ft. arch spans as shown on Plate 17.

(d) Quality of materials.

Where concrete is used, all administrations exercise close control over the quality of materials and the consistency of the mix at the site. The proportions set out in the Table are typical for mixes reported :

Part of structure	Proportions
Arch	1 : 1 1/2 : 3
Spandril walls	1 : 2 : 4
Backing	1 : 3 : 6

Vibration of the concrete is considered to be desirable, wherever this is possible, making use of internal vibrators. Very limited use is made of natural stone for the construction of masonry bridges by most administrations.

The Nizam's State Railway, India, which makes considerable use of natural stone lays down the following requirements :

Depth of courses — Varying from 1′ 6″ to 9″ minimum.

Regularity of courses — Each course must be of the same thickness, but bigger courses should not go over thinner courses.

Form of Bond — Through stones of at least 2-ft. length are used.

Depth of dressed surface — At least 3″ from the face.

Shape — Rectangular.

Joints — Cement bonding adopted for hard stones. Joints not to be thicker than 3/8-inch.

The Pennsylvania Railroad Co. alone reports the adoption of natural stone facing in some cases for masonry bridges constructed generally of other material, and the India Railway Board alone reports the use of artificial stone voussoirs, which are considered to be suitable for small spans, up to 30-ft. where it is desirable to reduce the effects of shrinkage.

None of the administrations which have reported, has made use of expanding cement in the construction of masonry bridges.

(*e*) *Waterproofing and drainage.*

Waterproofing practice varies. No waterproofing layer is provided by the Nizam's Railway, India and by the South African Railways and Harbours.

British Railways provide waterproofing, either as an asphalte layer, laid in two thicknesses, or latterly using layers of hessian based bituminous sheet, with bonding layers of bituminous material, and the waterproofing is preferred located on weak concrete backing laid to drainage falls.

Local requirements govern to some extent the location of drip pipes, particularly if the discharge must be into pipe drainage beneath the bridge. In such cases the Pennsylvania Railroad Company leads the surface water down the interiors of piers and abutments, and the Nizam's State Railway adopts this practice generally.

Other administrations place drip pipes through the arches or the spandril walls.

There is no uniformity in practice in the size of drip pipes, and their spacing and in the drainage falls to which backing is laid. Pipe sizes used are generally 3″ to 4″ diameter, but spacing ranges from 4-ft. to 15-ft., and drainage falls from 1 in 12 to 1 in 100. The local incidence of rainfall has no doubt led to such widely different practices.

It is generally considered to be of the utmost importance that adequate provision should be made to lead the water out of the structure as quickly as possible. Serious trouble has been experienced by British Railways on old arch bridges where the waterproofing and drainage arrangements have been inadequate, due to water percolation into piers and subsequent frost action.

(*f*) *Longitudinal joints.*

In those cases where a double track masonry bridge has to be built in two sections, whereby the portion to carry one track is completed before the portion to carry the other track, depending to some extent on the particular conditions at the site, it is generally considered to be sound practice to keep the two portions separate, and not to bond them together. On the Nizam's State Railway, India, only, is bonding the general practice in such cases.

Where the two portions are kept separate, it is the practice of British Railways and the Pennsylvania Railroad Company to build dwarf walls along the junction line of both portions, with the waterproofing turned up the inner face, and to provide inverted U-shaped slabs or plates, covering the joint.

(*g*) *Dynamic effects.*

The India Railway Board and the Nizam's State Railway, India, in accordance with the Indian Bridge Rules make reduction in the dynamic effect of the live load on masonry arches, according to the depth of fill and ballast beneath the track. A reduction on similar lines on an empirical basis is made by the South African Railways and Harbours administration.

The Pennsylvania Railroad Company makes no modification in the Dynamic Effect and uses the same basis for masonry bridges as for metal bridges. On British Railways, in the case of spans within the range for which amplification of the hammer-blow effect is taken into account in the dynamic increment as tabulated for metal bridges, no amplification of hammer blow effect would be taken into account for masonry arches.

(*h*) *Check rails and guard rails.*

The practice in providing check rails and guard rails on masonry bridges on British Railways and the Pennsylvania Railroad is on the same basis as for metal bridges. Elsewhere it is not considered to be necessary other than where curvature of the track would require the provision of check rails in any case.

(*i*) *Future developments.*

There is likely to be more extensive use of concrete for the construction of arch

bridges in the future. The India Railway Board envisages a wider use of concrete in box construction for culverts, and of rigid frames for bridges of suitable span, rather than arches.

D. — **Reinforced concrete underbridges**

(*a*) *Future development.*

The South African Railways and Harbours administration envisages wider adoption of the use of reinforced concrete for underbridges in the future, and on that system special study, investigations and trials are being pursued into cellular slab construction embodying metal or concrete pipes.

More extensive use on other administrations may accompany the adoption of standard designs for pre-cast units, as on British Railways, or the standardisation of formwork by the India Railway Board, but future developments in the use and economies of pre-stressed concrete may well influence present trends.

I. — **Underbridges comprising girders encased in concrete.**

(*a*) *General.*

The Nizam's State Railway, India, reports that this form of construction is not adopted. The Victorian Railways, Australia, makes wide use of slabs comprising rails encased in concrete, in accordance with standard designs as shown on Plates 18 and 19. This is the only form of this type of bridge used on that system.

Other administrations have type designs, but generally the requirements of each case, as governed by the available construction depth in relation to span often call for the development of special designs, conforming to type, but most appropriate for the conditions.

The India Railway Board and the South African Railways and Harbours limit the span for which the girders are embedded within the slab thickness to 15-ft. and 20-ft. respectively. No such limit is defined by British Railways or the Pennsylvania Railroad Company. Limited construction depth in many cases requires such close spacing of girders that there is no alternative to embedding the girders in the slab thickness. On British Railways, this type of bridge, comprising pre-cast slab units, with girders embedded in the slab thickness has been used up to spans of 36-ft., and on the Pennsylvania Railroad Company up to spans of 50-ft. The latter administration considers the practicable limit to be about 55-ft. Such a span is considered by other administrations to be beyond the economical limit for this form of construction. The India Railway Board limits the span to 15-ft., whilst the South African Railways and Harbours considers 45-ft. to be the economical limit.

(*b*) *Design basis.*

The basis for design varies. On British Railways and on the India Railway Board the metal beams are designed to carry the full load, a higher working stress than for plain steelwork being used on British Railways.

The Pennsylvania Railroad Company designs on the basis of the metal beams only carrying the load, particularly in the case of shorter span bridges, but for longer spans the design is based on composite action in cases where the provision of special arrangements to ensure such composite action can be justified.

Composite action is the basis for design by South African Railways and Harbours, with careful regard to bond and shear stresses, and in certain cases rails are bolted across the tops of the metal beams to ensure composite action.

There is considerable variation in the width of the slab over which the live load is considered to be distributed laterally, as the basis for design, ranging from a width 1-ft. greater than the length of sleepers by the India Railway Board, and 10-ft. by British Railways, to 13-ft. by the South African Railways and Harbours.

The dynamic increment provided for in design is the same as for metal bridges,

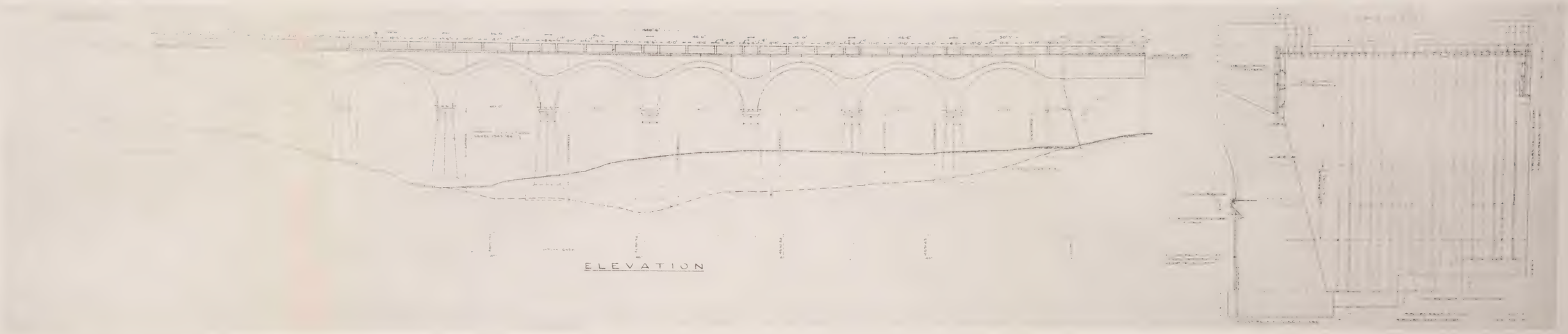
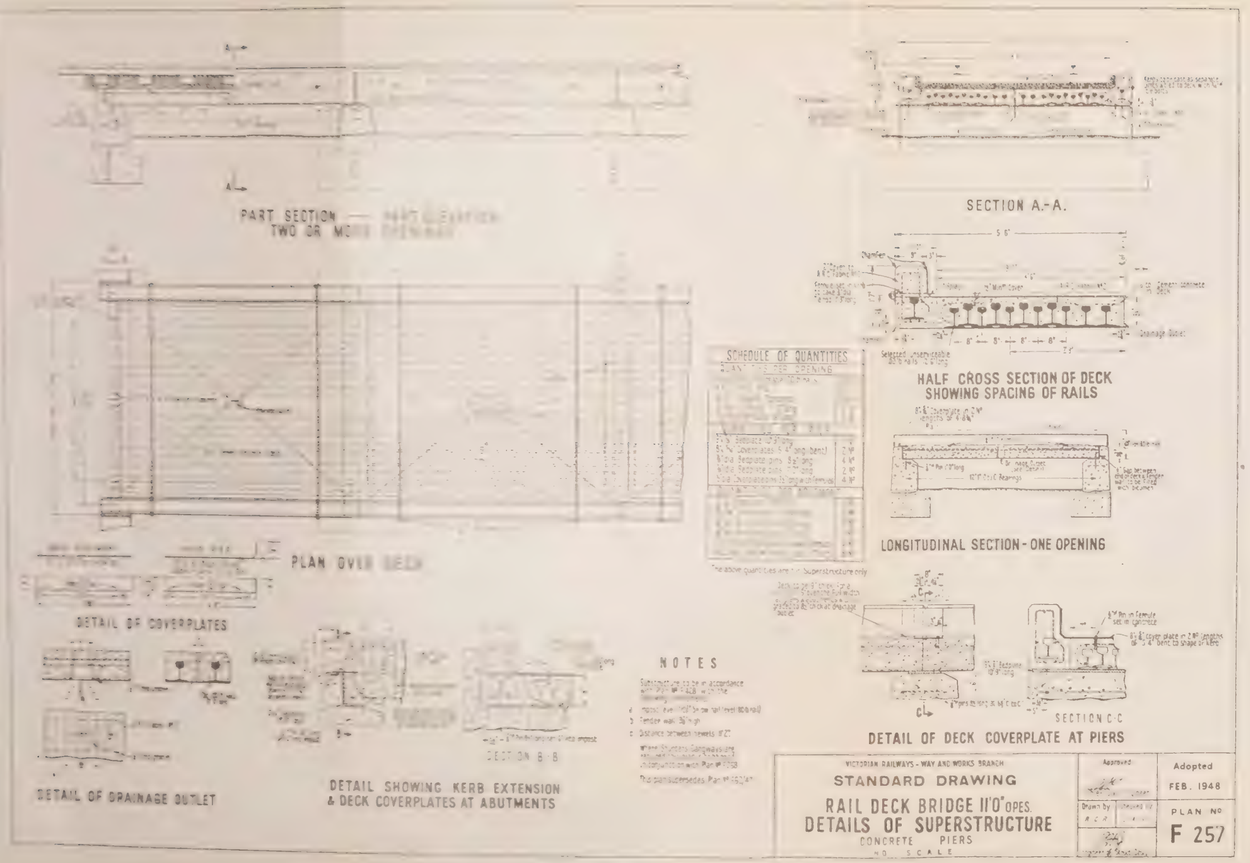
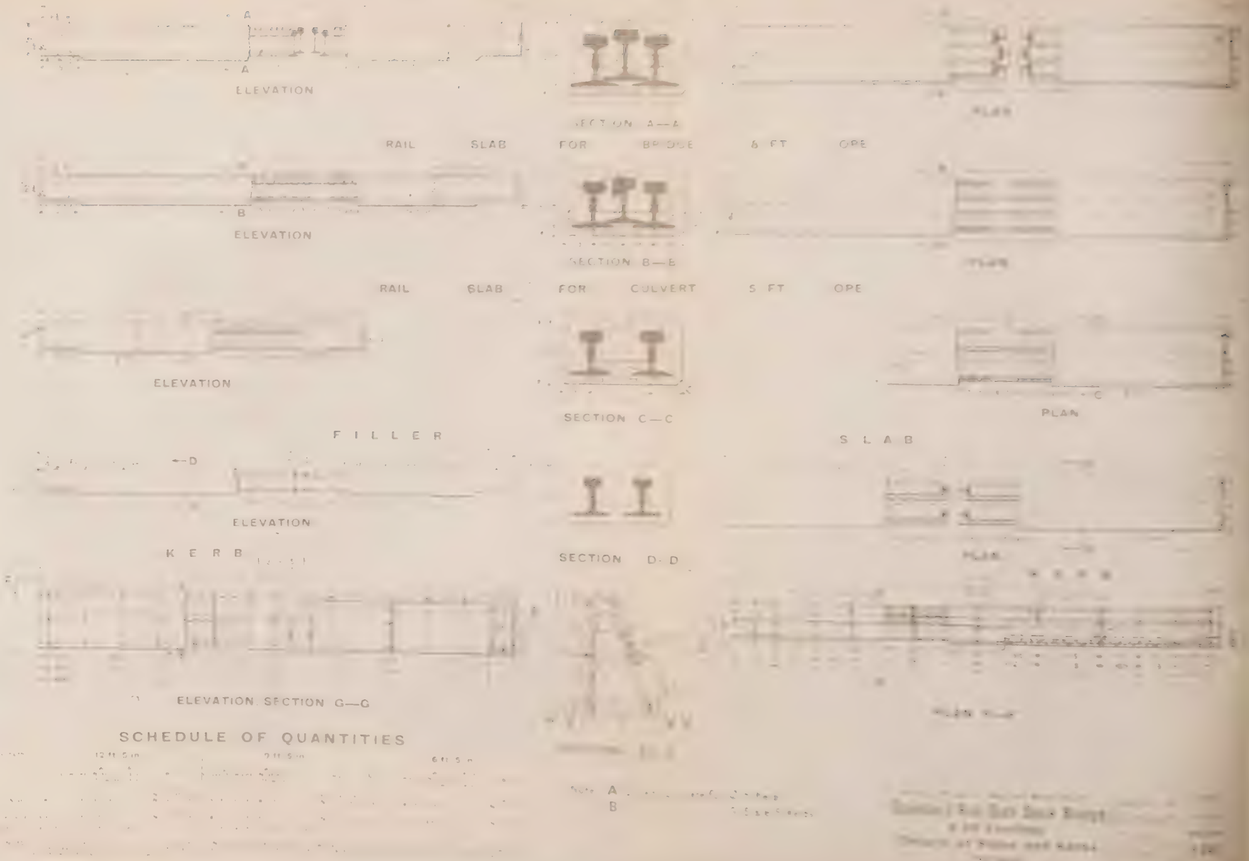


Plate 17. — South African Railways. — Grootvlei-Redan 8/40′—0″ arches over Klip river.


PART SECTION — ELEVATION
TWO OR MORE OPENINGS
SECTION A-A.
PLAN OVER DECK
SCHEDULE OF QUANTITIES
HALF CROSS SECTION OF DECK
SHOWING SPACING OF RAILS
LONGITUDINAL SECTION - ONE OPENING
DETAIL OF COVERPLATES
DETAIL OF DRAINAGE OUTLET
DETAIL SHOWING KERB EXTENSION
& DECK COVERPLATES AT ABUTMENTS
SECTION B-B
SECTION C-C
DETAIL OF DECK COVERPLATE AT PIERS
NOTES
VICTORIAN RAILWAYS - WAY AND WORKS BRANCH
STANDARD DRAWING
RAIL DECK BRIDGE 11'0" OPES.
DETAILS OF SUPERSTRUCTURE
CONCRETE PIERS
NO. SCALE
Approved
Adopted
FEB. 1948
Drawn by
Traced by
Checked by
PLAN NO.
F 257


RAIL SLAB FOR BRIDGE 5 FT OPE
ELEVATION
SECTION A—A
PLAN
RAIL SLAB FOR BRIDGE 8 FT OPE
ELEVATION
SECTION B—B
PLAN
RAIL SLAB FOR CULVERT 5 FT OPE
ELEVATION
SECTION C—C
PLAN
FILLER
SLAB
ELEVATION
SECTION D-D
PLAN
KERB
ELEVATION SECTION G—G
SCHEDULE OF QUANTITIES

except that the India Railway Board Rules permit reductions appropriate to the depth of filling and ballast between the underside of the track and the slab.

Much closer spacing between edges of flanges of metal beams is permitted by British Railways, the India Railway Board and South African Railways and Harbours, than by the Pennsylvania Railroad Company, ranging from 3″ to 7″ by the former to 15″ by the latter.

Transverse reinforcement is provided generally on an empirical basis, consisting of steel rods, flat iron bars, or old rails alone, or in cases where deep beams are used at fairly wide spacing, in combination with diaphragms between metal beam webs. Where the construction depth has permitted single beams to be used, located beneath the track rails, on British Railways the deck slab has been provided with reinforcement adequate to safeguard against failure of the slab in the event of derailment and to carry the propping for breakdown crane outrigger girders. (See Plate 20.)

No different basis for transverse reinforcement is reported as being adopted whether on single or double track bridges.

Administrations report that where this construction is adopted for skew bridges, the design is based on the skew span, the beams being located parallel to the general line of the tracks and the transverse reinforcement placed normal to the line of the beams. The South African Railways and Harbours, however, in case of bridges of which the width is approximately the same as the span, place the reinforcement parallel to the line of the abutments.

In the case of double track bridges of this type, the India Railway Board and South African Railways and Harbours prefer to construct as two separate and distinct slab units, whereas the Pennsylvania Railroad Company prefers single unit construction. On British Railways, this type of bridge is generally used to replace old bridges and is formed of pre-cast units, generally 3-ft. to 4-ft. wide placed side by side to build up the complete width of bridge deck required.

(c) Construction details.

On the Pennsylvania and South African Railways the bottom flanges of metal beams are exposed except where special circumstances, such as liability to corrosion, justify encasement.

When encased, as on the British Railways and the India Railway Board, reinforcing mesh is wrapped round the beam flanges prior to casting, and the mesh securely located. It is essential that the concrete casing of the undersides of beams should be of high quality and placed with care.

No special constructions at the ends of slab bridges are reported as considered to be necessary. It is considered to be good practice on British Railways for pre-cast slab units to oversail the back of the bearing beams on the abutments, and for a throat to be formed near the end of the underside of the slab— as a measure to avoid seapage of water through to the face of the abutment. (See Plate 21).

South African Railways alone reports that outside the width of the tracks the level of the top of the slab is brought up to rail level, to form a footway. Elsewhere the same level of the top of the slab is generally maintained across the whole width of the bridge, with stout kerb walls on the extreme edges. No useful purpose is seen in providing a specially paved walkway on this type of bridge.

Waterproofing is not generally provided on this type of bridge deck, except on the Pennsylvania Railroad. Layers of hessian reinforced bituminous sheet and bituminous medium is widely used either for covering joints or for the entire waterproofing of the surface of the slab, with asphaltic concrete or tiles overlaid for protection.

There is wide variation in the drainage falls considered to be necessary — ranging from 1 in 40 to 1 in 200, with drip pipes ranging from 1 1/2″ to 4″ diameter, generally provided at about 15-ft. spacing when it is not appropriate to drain to the ends of the bridge.

The minimum depth of ballast required on this type of bridge is generally 8″, both

for straight and curved tracks, although on British Railways a minimum of 4″ is permitted.

(*d*) *General comments.*

This type of bridge is considered by all reporting administrations to be most useful and economical for the general range of requirements for short and medium spans. It can be used in cases of limited construction depth other than where the limitation is most stringent. When constructed in the form of pre-cast units, replacement of existing bridges can be carried out speedily and with minimum interference with the speed of traffic. Where constructed « in situ » the metal beams provide a medium themselves for the temporary support of the tracks in service.

In practically every case where adopted, tracks are ballasted, and maintenance costs are low.

F. — **Road bridges and overbridges.**

(*a*) *Construction.*

The choice of material for the construction of overbridges is generally governed by the relative economics of possible alternatives in relation to the particular circumstances in each case. Such circumstances include the location, in relation to sources of alternative materials, liability to corrosive influences, and the available construction depth in relation to the span.

British Railways and South African Railways make use of concrete construction as widely as possible, whilst the Victorian Railways, Australia, generally finds steel the most economical medium.

Most overbridges constructed on British Railways conform to a limited range of type designs, Type designs comprising longitudinal steel beams with concrete decks, and slabs with embedded rails are widely used on Victorian Railways, Australia.

An interesting type of design for short span overbridges has been developed on British Railways, and a number of bridges have been constructed in accordance therewith. The design comprises shallow prestressed concrete I-beam units, which are placed with bottom flanges edge to edge for the complete width of the bridge. Thereafter a monolith slab deck is completed with concrete placed « in situ ».

Although site conditions usually strictly limit the freedom of choice for the form of construction of overbridges in stations, the use of long spans is preferred generally. Such long spans give greater flexibility in the planning of track layout alterations and improvements and the wide use of colour light signals tends to eliminate one of the disadvantages.

On Plate 22 is shown a long span footbridge on British Railways, in the centre of a big station, and the design is interesting both as an application of welded construction, and in the arrangement of the column supports and the stairs.

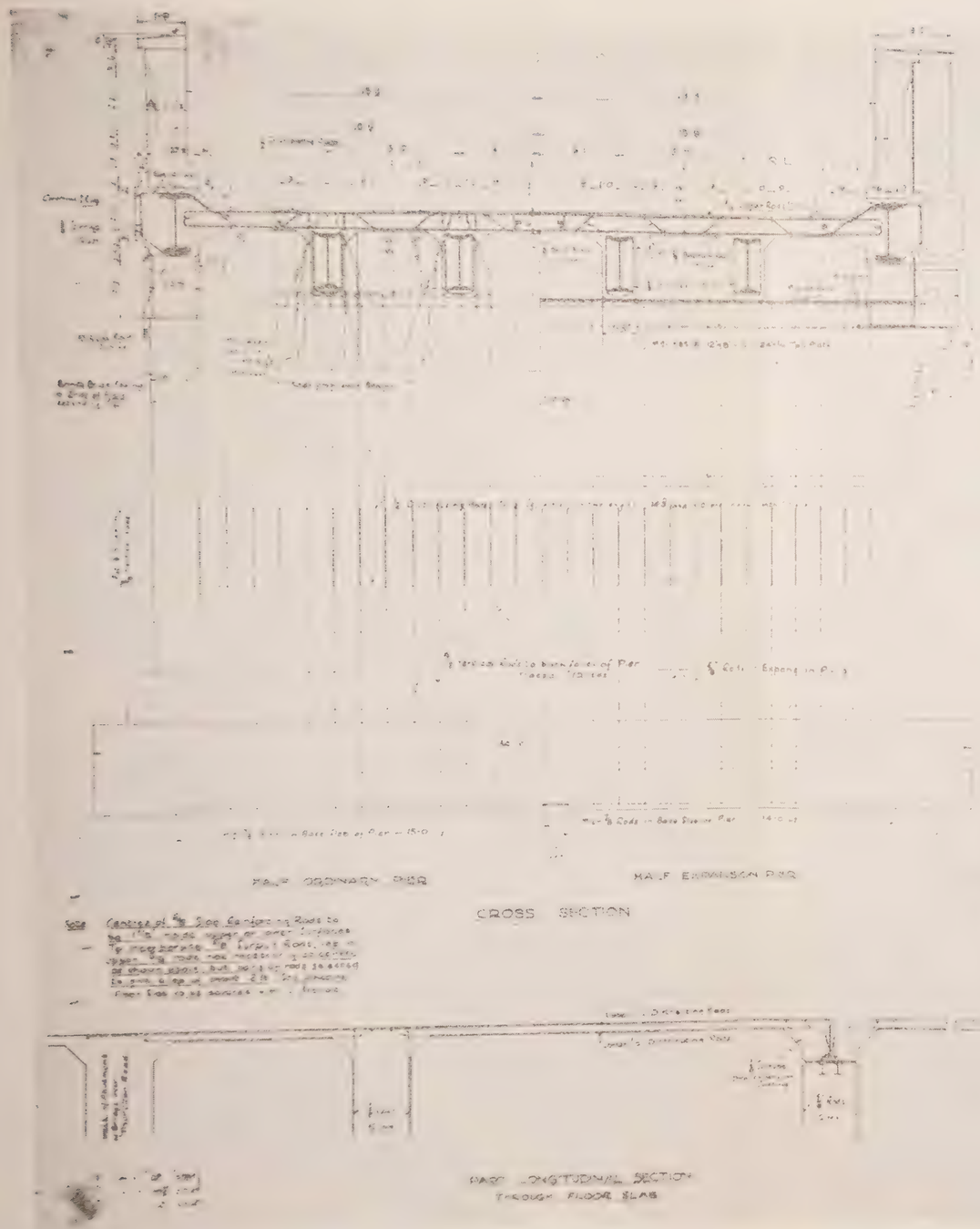
Welding has been used only to a limited extent up to the present time on the fabrication of steel overbridges. Where it has been adopted in the fabrication of girders only, with riveted or bolted site joints, by the India Railway Board, the results have been quite satisfactory.

Special steels or light weight alloys have not yet been adopted by any of the administrations who have reported.

Decks of reinforced concrete, or steel beams embedded in concrete, or comprising steel beams, jack arches, and concrete, are considered suitable forms of construction where metal main girders are used. The South African Railways and Harbours prefers decks of metal troughs, in such cases, filled with concrete. In wide bridges the trough decking is supported on a system of steel cross-girders and rails-bearers.

(*b*) *Bearings.*

The limit of span above which it is considered necessary to provide roller bearings in the case of metal beam overbridges ranges from 60-ft. to about 100-ft. on the reporting administrations. Similar limits are set for concrete beam overbridges



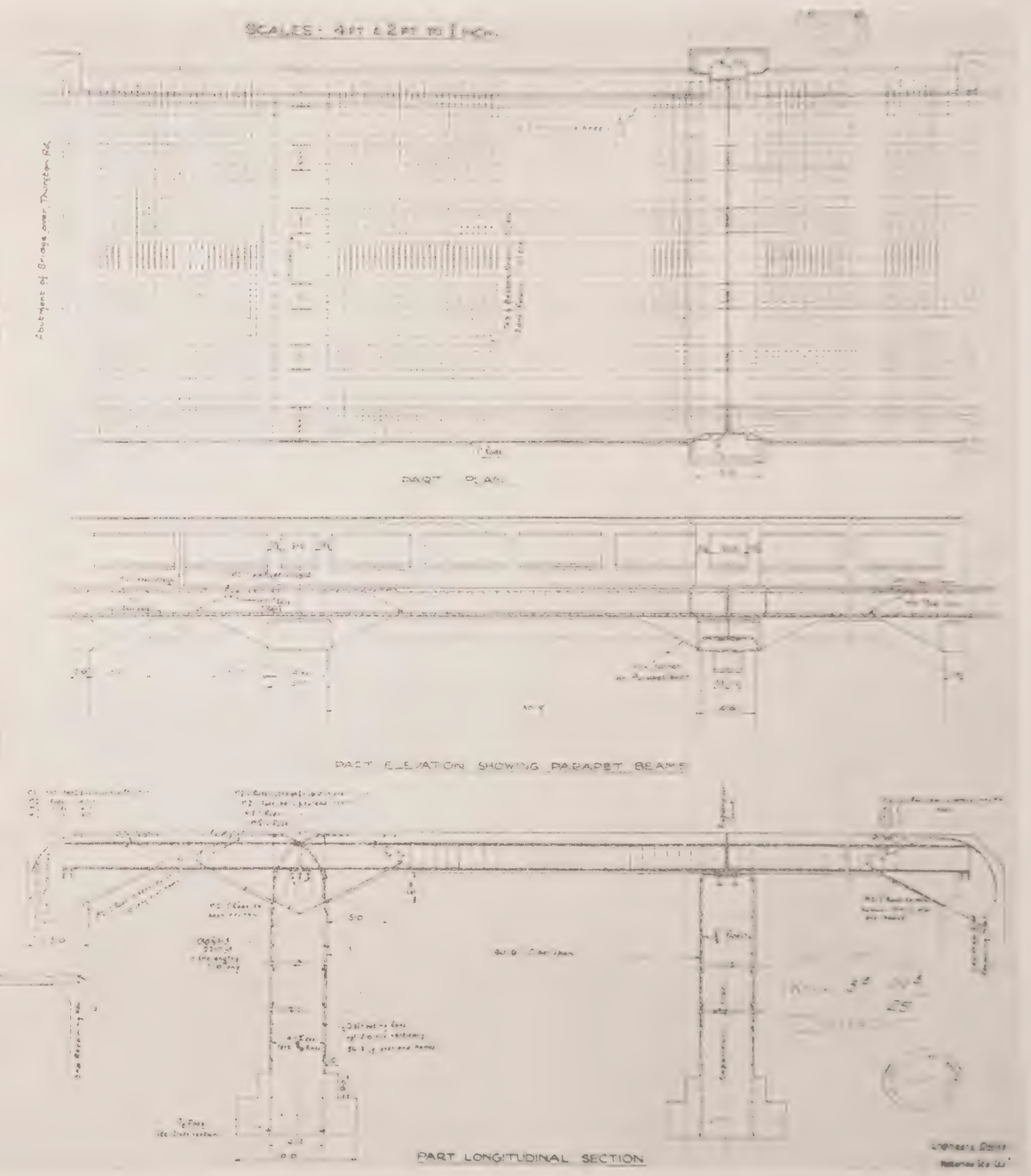


Plate 20. — Southern Railway. Lewisham connecting line-viaduct (Arrangement of beams and reinforcement).

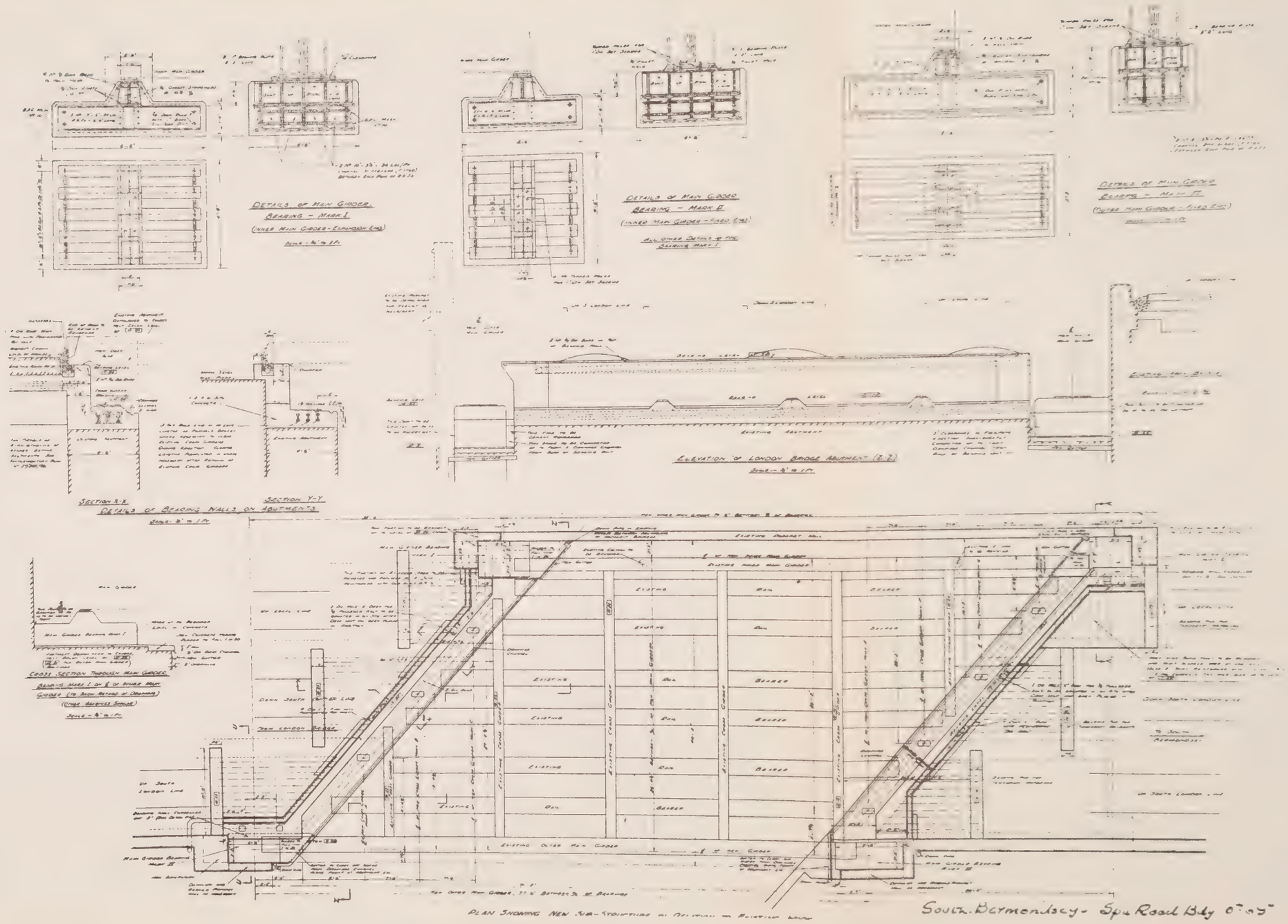

DETAILS OF MAIN GIRDER BEARING – MARK I
(INNER MAIN GIRDER – EXPANSION END)
DETAILS OF MAIN GIRDER BEARING – MARK II
(INNER MAIN GIRDER – FIXED END)
ALL OTHER DETAILS AS FOR BEARING MARK I.
DETAILS OF MAIN GIRDER BEARING – MARK III
(OUTER MAIN GIRDER – FIXED END)
ELEVATION 'A' LONDON BRIDGE ABUTMENT (E.F.)
SECTION X-X
SECTION Y-Y
DETAILS OF BEARING WALLS ON ABUTMENTS
CROSS SECTION THROUGH MAIN GIRDER
PLAN SHOWING NEW SUB-STRUCTURE IN RELATION TO EXISTING WORK
South Bermondsey - Spa Road Bdg 0'-0"

Plate 23. — South Bermondsey. — Spa Road Bridge.

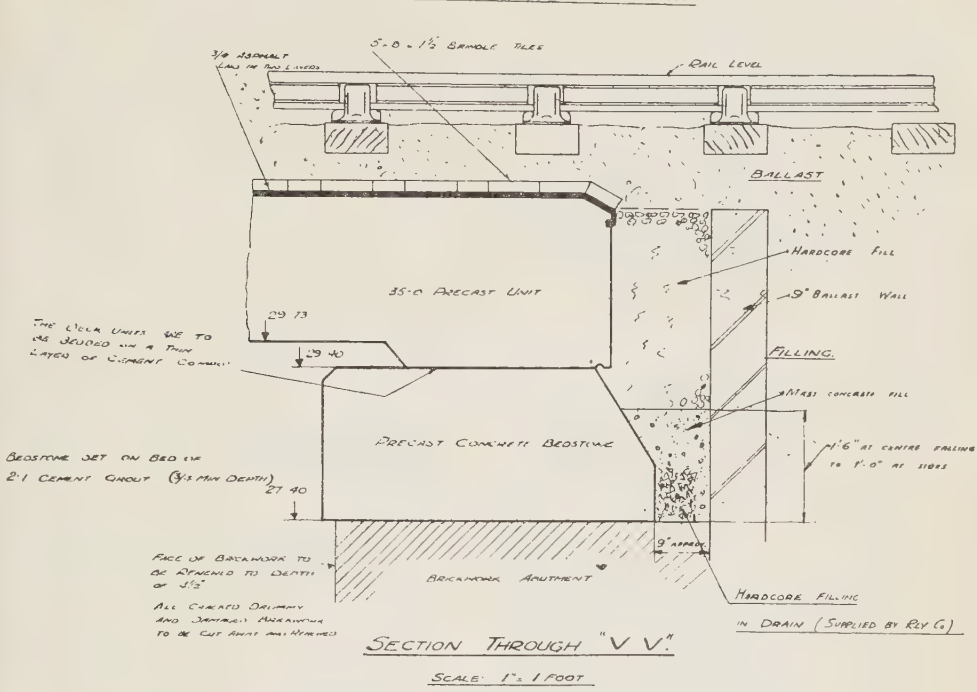


Plate 21.

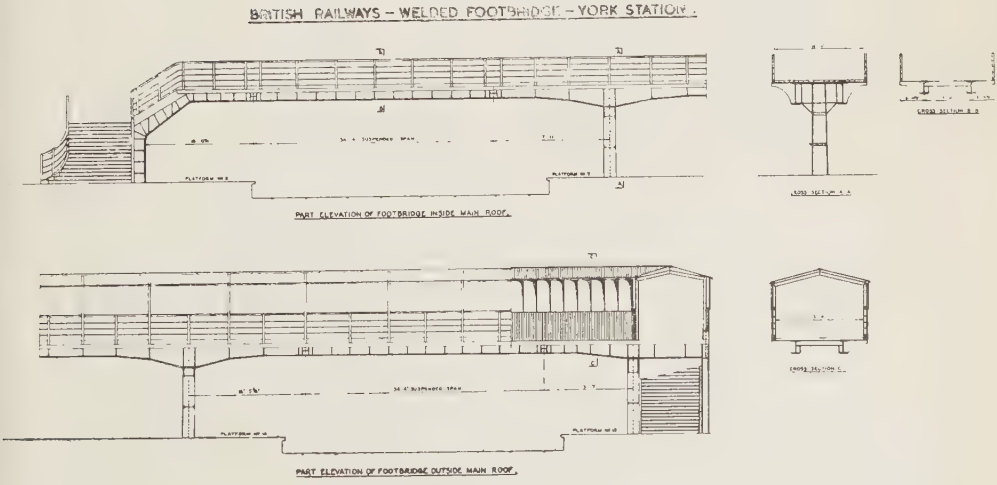

BRITISH RAILWAYS – WELDED FOOTBRIDGE – YORK STATION.
PART ELEVATION OF FOOTBRIDGE INSIDE MAIN ROOF.
PART ELEVATION OF FOOTBRIDGE OUTSIDE MAIN ROOF.

Plate 22.

by those administrations who have adopted concrete for such longer spans, although South African Railways and Harbours, whilst placing the limit at 80-ft. for steel bridges, considers that roller bearings should be provided for concrete beam bridges of spans 60-ft. and over.

Concrete slabs are bedded direct on to the abutments, but where separately encased metal beams are used, generally for spans exceeding about 30-ft., metal bearing plates are provided.

(*c*) *Dynamic effect of live load.*

The various bases on which provision is made in the design of road overbridges for the dynamic effect of the live load are as follow :

(i) *British Railways and South African Railways.*

In accordance with Ministry of Transport Loading Requirements for Highway Bridges, which provides for :

(*a*) For slabs, stringers and girders of 100 feet span or less and hangers and connections to them :

An impact allowance of 50 per cent to be added to the individual concentrated load which produces the greatest bending moment or shear, as the case may be.

(*b*) For members exceeding 100 feet span, impact may be ignored.

(ii) *The Pennsylvania Railroad Company.*

In accordance with the American Association of State Highways Officials' Specifications.

$$I\ (\text{Impact } \%) = \frac{5\,000}{125+L}$$

L = span length (feet).

(iii) *India Railway Board.*

In accordance with the following schedule of factors, for use with Class A highway loading :

Span feet	Moments Impact factor	Shears Impact factor
1	5	9
5	0.55	0.55
10	0.50	0.50
15	0.46	0.46
20	0.41	0.41
25	0.375	0.375
30	0.340	0.340
40	0.305	0.305
60	0.261	0.261
80	0.228	0.228
100	0.202	0.202
150 to 500	0.15	0.15

(iv) *India — Nizam's State Railway.*

100 % over static live load is provided for on bridges up to 20-ft. span, and reductions made for longer spans.

(v) *Victorian Railways, Australia.*

$$I\ (\text{Impact } \%) = \frac{5\,000}{L+125}$$

not to exceed 30 %, not to be less than 10 %.

L = span (feet) or loaded length to give maximum stress.

(*d*) *Junction with road approach slab.*

For short span concrete bridges it is generally not considered necessary to make any special provision at the junction between the deck slab of the bridge and the roadway slab.

In other cases it is considered to be advisable to make a definite joint between the ends of the roadway carried by the bridge and the approach roadways. Constructions adopted at such joints include metal comb plates, small free slabs spanning a gap between the bridge deck and the approach roadway foundation, flat slide plates, and bituminous filling.

(*e*) *Waterproofing and surfacing.*

Special waterproofing of the decks of road bridges is considered to be unnecessary in most cases. It is general practice, except for light traffic roadways, to provide a wearing surface on the bridge deck, either of asphaltic or bituminous composition. In some cases special concrete wearing surfaces have been provided.

(*f*) *Tramway rails on bridges.*

Various methods of fixing tramway rails on to road bridge decks are reported. Where the space occupied by the tramway track must form part of the road surface, the general practice is for the rails to be bedded on to the bridge deck and concreted in solid up to the roadway wearing surface. The provision of ash timber packings to the rails is recommended by one administration. Fixing with clips and anchor bolts is also recommended.

(*g*) *General comments.*

The view is held that all-concrete superstructures are likely widely to supersede other forms of construction for the more normal spans of bridges carrying roads over railways, although the Victorian Railways, Australia, envisages a predominance of the use of metal beams with concrete decks. The India Railway Board reports a tendency to employ concrete ribs or beams with curved soffits and cantilever ends carrying suspended spans, in the case of multi-span bridges, with the decks forming part of the upper flanges of the main ribs or beams.

Alternative designs of pre-stressed concrete overbridges are being developed and constructed on British Railways, and wider use of this form of construction is probable.

G. — **Piers and abutments.**

(*a*) *Constructions.*

Mass concrete is widely used at the present time in the construction of piers and abutments, but not to the exclusion of other forms of construction when they are more appropriate and economical for the particular circumstances.

Thin reinforced concrete piers or steel trestles, are used on some railways where the width available for the construction of the pier is limited.

Little use is made of natural stone, except on the Sudan Railways and the Nizam's State Railway, India.

All administrations report the general use of concrete as the medium for construction of the parts carrying load concentrations. These are suitably reinforced so that they constitute distributing beams. Steel grillages, embedded in concrete are also used on British Railways, and a good example of recent grillage and bearing construction is shown on Plate 23.

The India Railway Board and the Nizams' State Railway indicate a preference for wing walls to be constructed as straight walls, splayed back from the line of the abutment. Other administrations vary practice according to local conditions.

Varying views are also reported on the desirability of providing separating joints between abutments and wing walls. The Pennsylvania Railroad and the Sudan Railways would generally adopt solid construction, except where the foundation at a particular site prompts special consideration for settlement. Other administrations consider that it is wisest to separate wing walls from abutments as a general practice to avoid the cracking which has resulted from unequal settlement at many bridges in the past.

(*b*) *Special constructions.*

Very limited use is reported of special constructions in thin reinforced concrete beams, slab, and wall units. South African Railways and Harbours whilst generally avoiding thin walled construction reports a particular example, as shown on Plates 24 and 24A.

Box type abutments are thought by the Nizams' State Railway to be economical for heights exceeding 20-ft. A number of bridge abutments recently constructed on

British Railways have been in the form of hollow boxes with thin walls, as shown on Plate 25.

An interesting design of abutments for a double track bridge comprising two lattice girder spans of about 120-ft. is shown on Plate 26. Due to the heavy skew of the bridge, the thin walled abutment design adopted was economical and enabled a simple and clean arrangement of bridge floor to be provided at the acute skew ends.

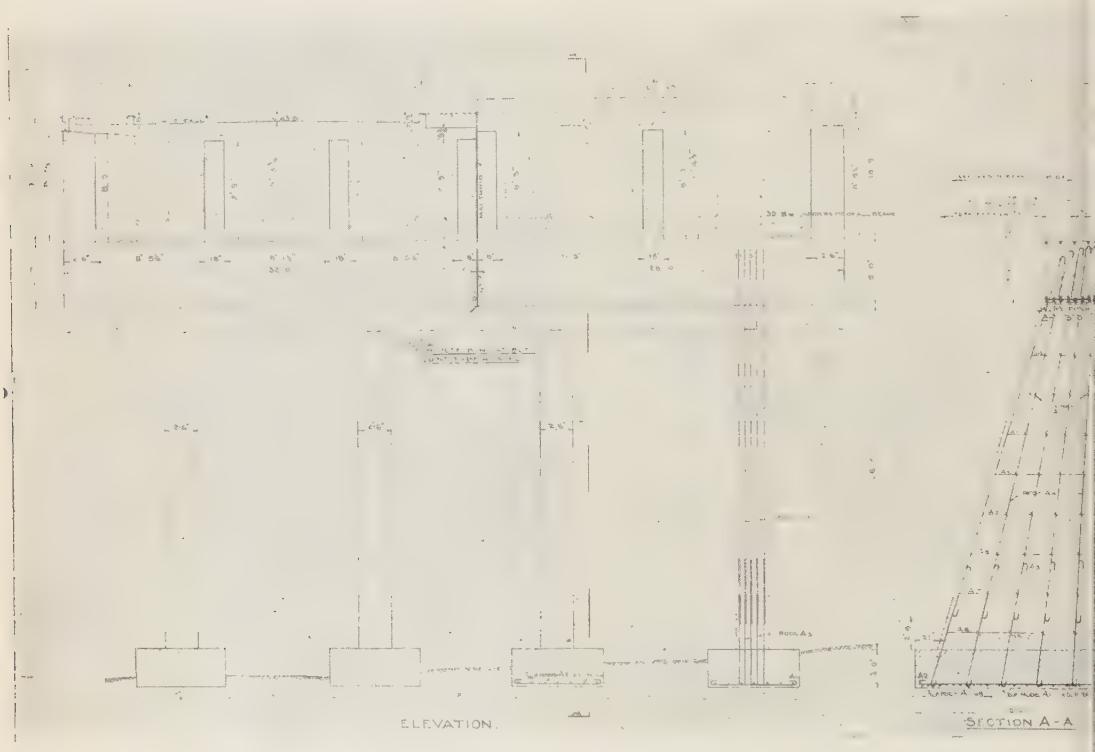


Plate 24. — South African Railways and Harbours. — Combined road and rail bridge, over Umkomaas river. South abutment.

(c) Provision for horizontal forces.

It is gathered from reports that for the more usual range of height and span of bridges, abutments and piers are designed in the first place appropriate for the main direct loading, and then reviewed in relation to their capacity to transfer all or part of the horizontal forces acting at deck level to the foundations, depending on the length, form of construction of the bridge and whether tracks are ballasted or not.

For multi-span bridges, the Pennsylvania Railroad Company locates fixed bearings on the abutments if possible; other administrations locate both fixed and expansion bearings on intermediate piers, although some arrange for two fixed, or two free bearings on the same pier, whilst others arrange one fixed and one free bearing on the same pier.

(d) General comments.

The present tendency, as reported, is to the use of mass concrete abutments and

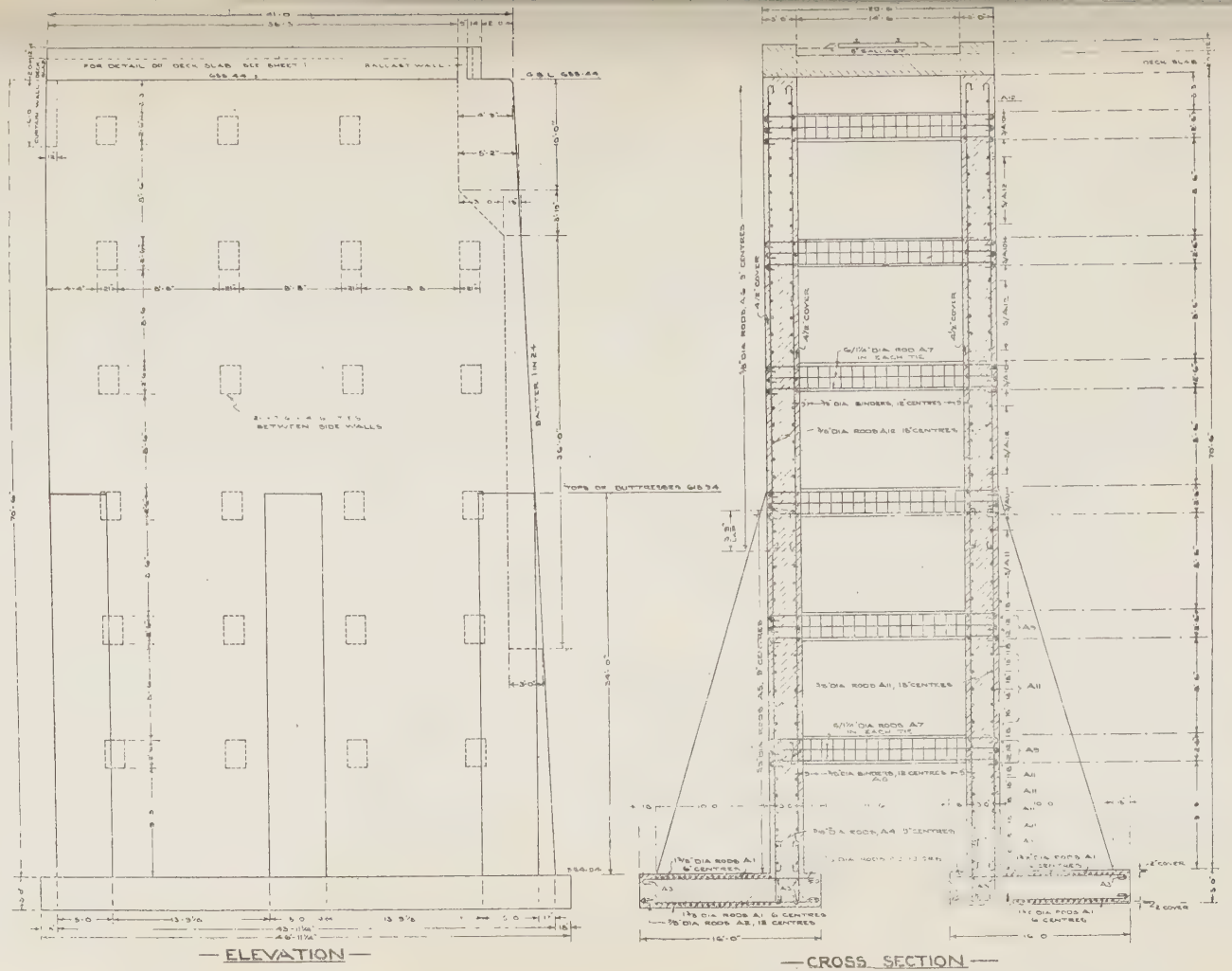


Plate 24A. — South African Railways and Harbours. — Amabele-Umtata 9/130′—0″ through spans over Great Kei river. Detail of Amabele abutment.

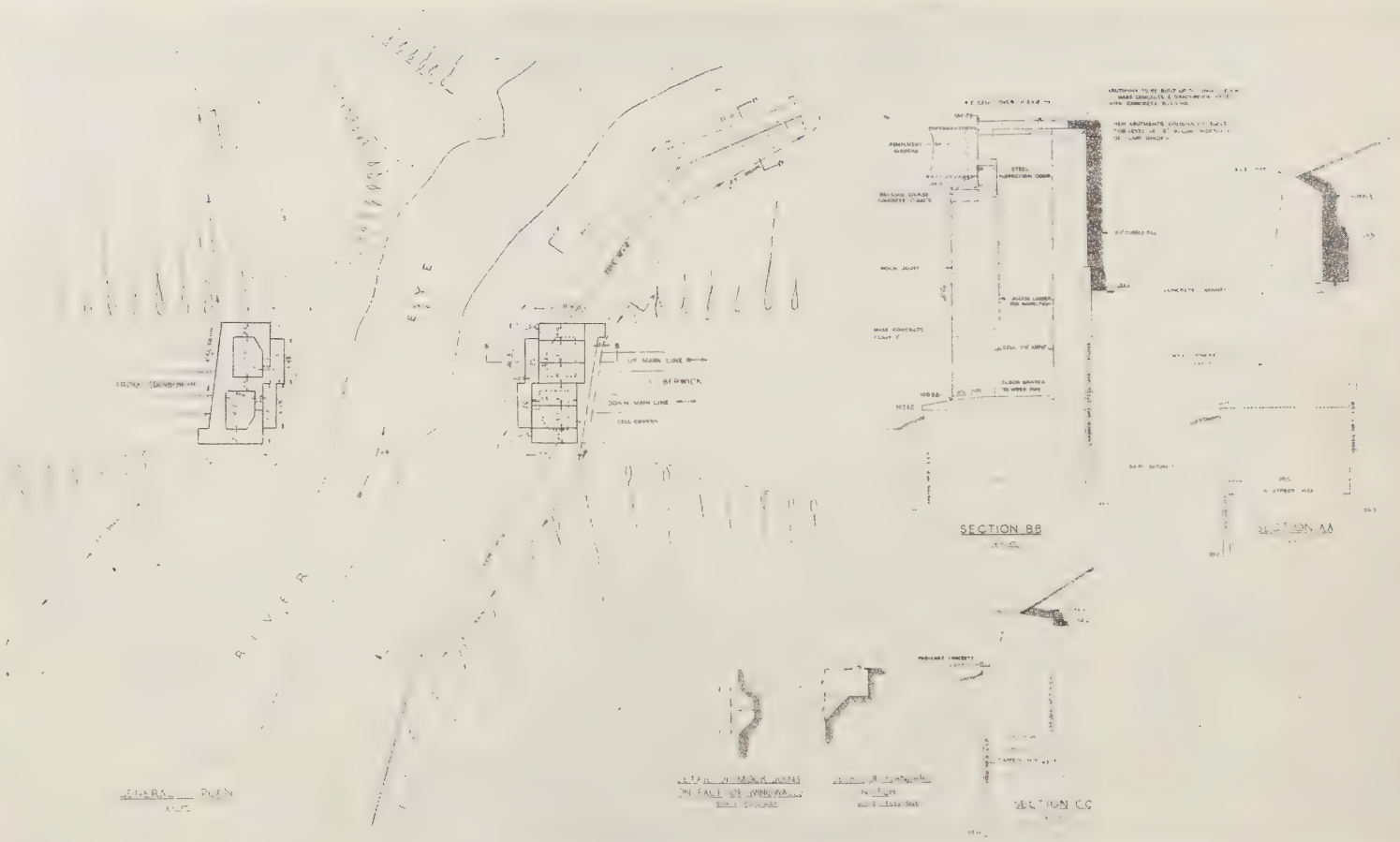
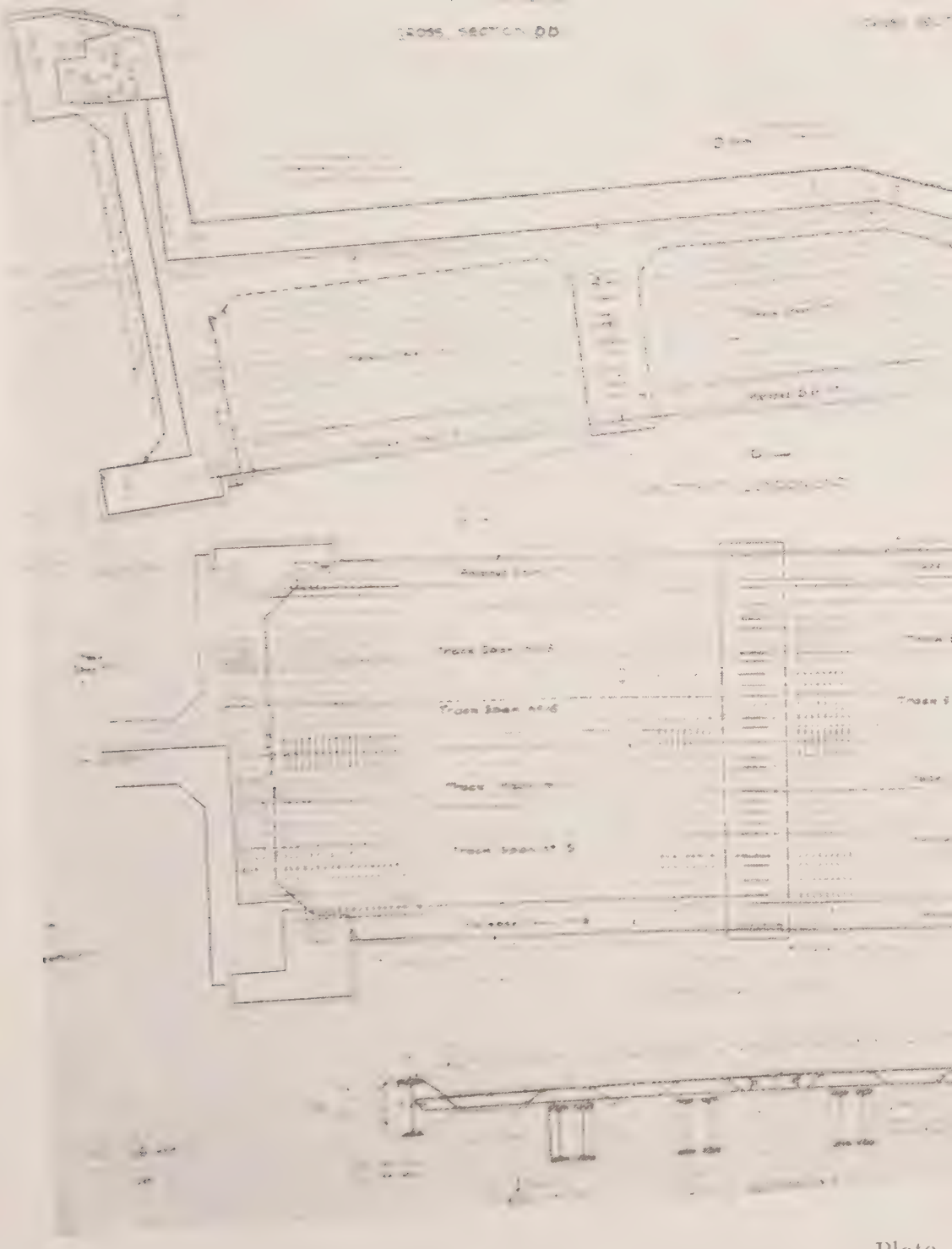


Plate 25.



Platc

Plate 27. — Edinburgh-Berwick main line bridge.

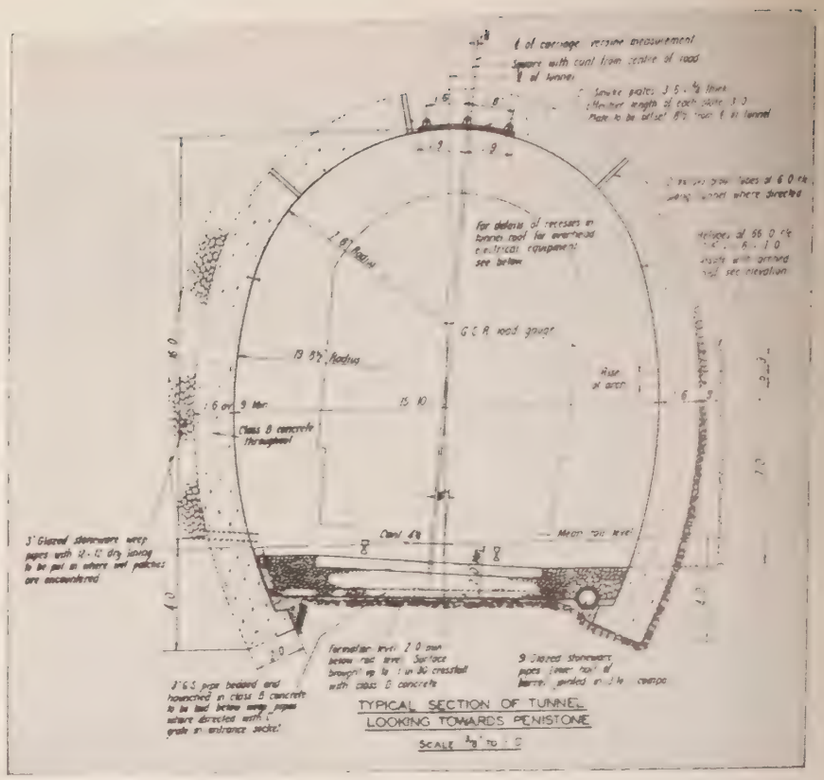


Plate 28. — Thurgoland tunnel.

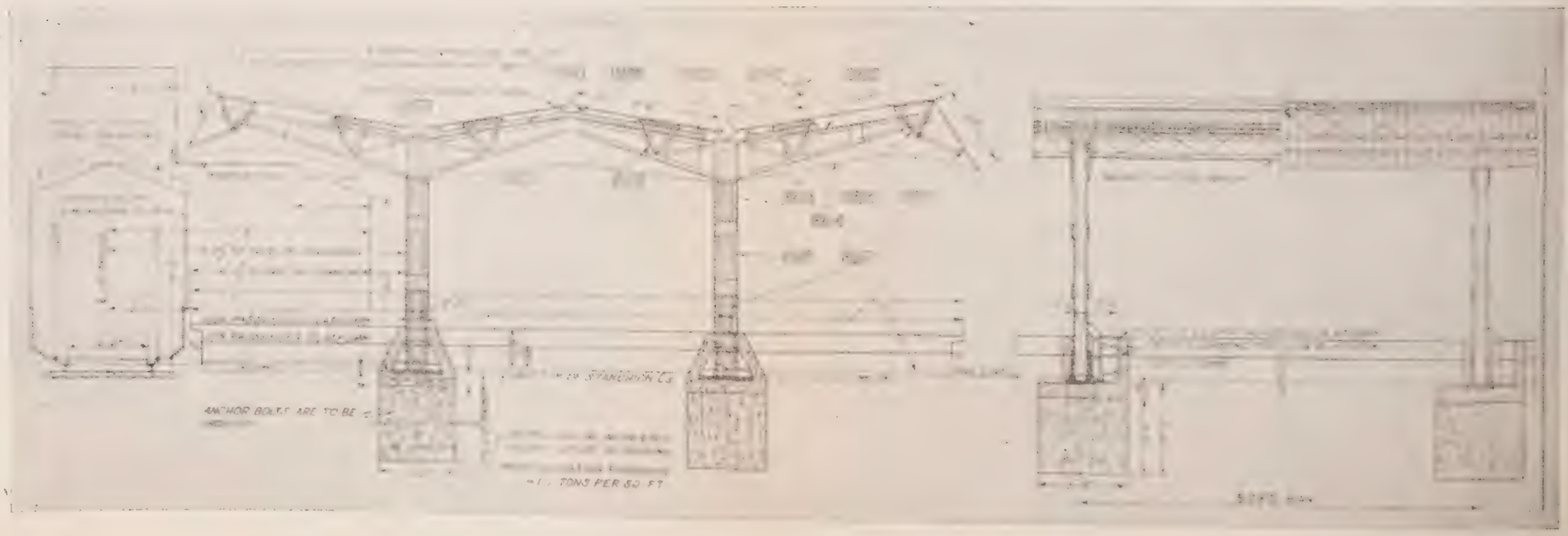


Plate 29. — India Railways. — Island passenger platform roof.

piers. Special facing is avoided by British Railways except where local aesthetic requirements justify, but the use of horizontal rebates in the exposed concrete faces of abutments, piers and walls is favoured to relieve the otherwise plain concrete surface and to conceal horizontal joints between succeeding lifts of concrete.

On Plate 27 is shown a very recent example of abutment and wing wall construction on British Railways.

The effect of the provision of horizontal rebates in the force of the mass concrete work is clearly visible, the design of the work being as shown on Plate 25.

On the other hand, the India Railway Board reports the increasing use of pre-cast concrete facing blocks, whereby the use of shuttering is avoided, the blocks being bonded into the mass concrete.

The South African Railways and Harbours reports that in all cases a framework of vertical reinforcement is used, generally comprising old rails, to safeguard against unforeseen weakness in horizontal construction joints. This reinforcement also permits abutments to be designed as semi-gravity walls.

H. **Retaining walls.**

All administrations report that hitherto the design of retaining walls has been based on the application of semi-empirical formulae to determine the loading from the ground retained, and the sliding and heaving resistances to be expected from the foundation. Test holes, borings, and soil loading tests « in situ » have all been adopted in the past and continue to be used in cases where it is desirable to supplement an assessment based on general experience.

British Railways and the India Railway Board are developing the practice of soil sampling and testing and in future more precise information on the characteristics of the soil at a site will be obtained, where desirable, to supplement experience and evidence available otherwise as a basis for design of earth retaining walls.

J. — **Tunnels.**

Few of the administrations report experience of the behaviour of concrete lined tunnels and where there is experience no special measures are considered to be necessary to safeguard against deterioration of the concrete from steam locomotive fumes and moisture.

A concrete lined tunnel recently completed by British Railways has been provided with continuous cast iron smokes plates located at the surface of the tunnel lining, immediately above the centre of the track, Heavy traffic, hauled by steam locomotives passes through this tunnel on a rising gradient, and the cast iron smoke plates have been provided to safeguard against deterioration of the concrete, in view of the limited vertical height of the lining above the top of engine funnels. (See Plate 28.)

No experience of any difficulties due to electrical leakage from overhead conductors due to dampness is reported. In the construction of a new concrete lined tunnel substantially through disturbed rock formation now in progress on British Railways, steps are being taken to provide positive means to collect and convey into the drainage system all main water runs encountered during driving and to seal elsewhere.

K. — **Platform roofs.**

(*a*) *Construction.*

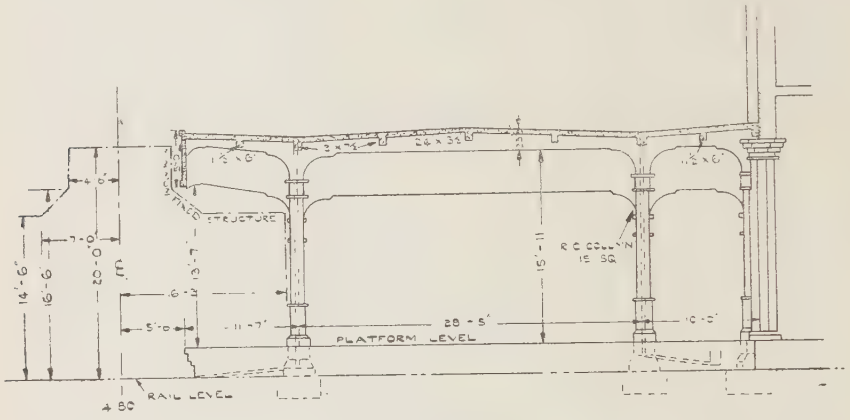
Wide use is made of constructions comprising corrugated iron or asbestos cement cladding, carried on steel framing of a variety of forms, including steel trusses and purlins, umbrella or butterfly framings, single and double cantilever beams and principals. Nevertheless it cannot be reported that any of these constitute standard forms of construction adopted to the exclusion of all others by any of the reporting administrations.

The Pennsylvania Railroad Company makes use of wood, metal and concrete, according to local advantage.

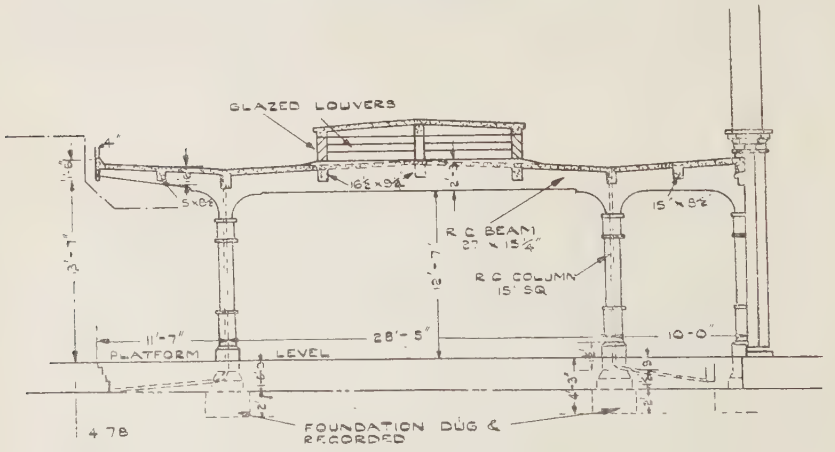
The India Railway Board has used reinforced concrete cantilevers with sus-

pended corrugated asbestos sheeting and further designs for reinforced concrete roofs are being developed. The construction shown on Plate 29 is typical of recent construction in steel.

which examples are shown on Plates 31 and 31A, whilst the present tendency on British Railways is towards the use of welded steel cantilever or buterfly framing with corrugated asbestos cement or stressed



Section C. D. only.



Section A. B. only.

Plate 30. — Nizam's State Railway : Roofing B. G. main platform. — Secunderabad.

Reinforced concrete slab roofs, are adopted sometimes by the Nizam's State Railway, India, as shown on Plate 30.

Concrete cantilever and concrete shell roofs have been used on British Railways and by the London Transport Board, of skin plywood cladding, of which a recent example is shown on Plate 32.

(*b*) *Glazing.*

The incorporation of glazing in platform roofs, other than to fulfil some particular

Plate 31. — Malden Manor Station. — Concrete shell roof.

Plate 31A. — Northolt Station : Concrete shell roof.

local requirement appears to be exceptional, other than on British Railways and London Transport, where it is the usual practice to provide a proportion of glazing in the roof cladding at heavily used stations particulary in the London area. In many such cases, the intent, in providing the glazing on British Railways, has been to assist in the rapid entraining and de-training of big numbers of passengers, or to economise in the use of artificial lighting. (See Plate 32.)

India varies with the locality, and the loading adopted by the Victorian Railways, Australia, is based on a wind speed of 80 m. p. h. and a pressure of 20-lbs. per square foot on a surface normal to the direction of the wind.

British Railways and South African Railways take account of both pressures and suction forces arising from the wind, where these can act simultaneously.

Plate 33 shows the form of distribution

Plate 32. — British Railways. York Station : roof to platform 14.

(*c*) *Loading basis for design.*

The asymmetry of loading adopted for the purposes of design of roofs is governed by the form of construction of the roof, according as to whether or not asymmetrical loading due to snow (where likely) or wind, will be the governing condition in respect of the main framework.

The Pennsylvania Railroad Company design on the basis of 30-lbs. per square foot horizontal wind pressure on the projected area of the roof and a vertical pressure of 10-lbs. per square foor.

The intensity wind loading adopted in of wind loading recommended for adoption on British Railways for the design of platform awnings of more modern forms of construction, as determined from special wind tunnel experimental work.

L. — **Testing of bridges.**

(*a*) *General.*

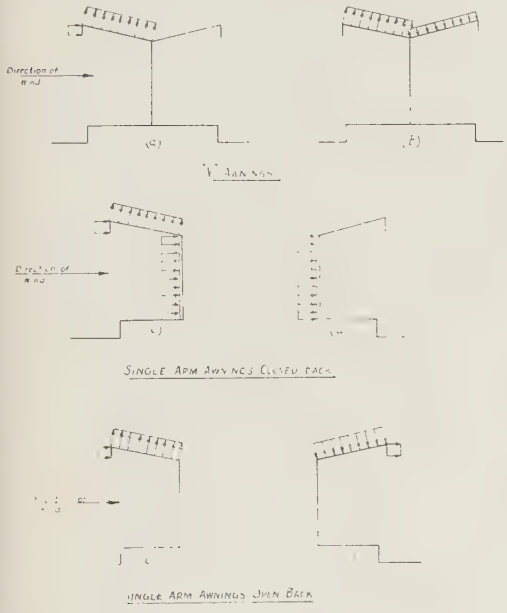
It is not the practice on any of the administrations which have reported, to carry out instrumental tests on existing bridges at regular intervals.

Most railways confirm by recordings of deflections or strain meter recordings,

prior to the opening of a new bridge, that its behaviour under load is within the requirements forecast from the design.

The Pennsylvania Railroad Company reports that tests are very rarely carried out on bridges in view of the very comprehensive series conducted by the American Railway Engineering Association in the past.

or proposed loading. The object of such tests is to determine as precisely as possible the manner in which the mutual assistance of the various parts of a bridge in carrying the live load results in actual stresses being different from those derived by the normal methods of calculation. Such mutual assistance generally results in actual stresses being lower than the calculated ones.



TYPE	CONDITION		PRESSURE LBS/FT² OVERALL STABILITY A 1	A 2	B 1	B 2	MOMENTS IN ARMS A 1	A 2	B 1	B 2
Approx Symm 'V'	Windward Arm		-24.5	-32.0	-18.0	-24.5	-24.5	-32.0	-18.0	-24.5
	Leeward Arm		0	0	0	0	+5.5	+7.0	+4.0	+5.5
Single Arm	Back Closed	Wind From Front	-24.5	-32.0	-18.0	-24.5	-24.5	-32.0	-18.0	-24.5
		Wind From Back	0	0	0	0	0	0	0	0
	Back Open	Wind From Front	-14.0	-18.0	-10.5	-14.0	-14.0	-18.0	-10.5	-14.0
		Wind From Back	+14.0	+18.0	+10.5	+14.0	+14.0	+18.0	+10.5	+14.0
	Walls at Back of Awnings		+19.0	+25.0	+14.0	+19.0	–	–	–	–
Both	Valances & Edge Beams		+11.0	+14.0	+8.0	+11.0	+11.0	+14.0	+8.0	+11.0

Plate 33. — Wind pressure on awning roofs. (British Railways).

On the Sudan Railways, the general freedom from corrosion and the slow speed of traffic do not give rise to conditions calling for « in situ » testing of bridges.

No tests are carried out by the Victorian Railways, Australia.

In India, the Railway Board and the Nizam's State Railway make instrumental investigations in particular cases when undesirable developments are apparent.

On British Railways, tests are undertaken on metal bridges when the normal calculations for assessing their capacity, lead to doubt as to their adequacy to carry existing

Deflection tests have been carried out on bridges comprising concrete slabs either with metal girders embedded, or reinforced, to confirm the lateral distribution of the live load amongst the several units comprising the complete width of the deck.

Both deflection and strain meter recordings have been made on brick arches and piers, in special cases where abnormal movement has been apparent, to give guidance in the assessment of their capacity and to confirm elastic behaviour.

The South African Railways and Harbours conducts tests on bridges when it is

proposed to run heavier engines, to enable the probable total dynamic effects to be evaluated as precisely as possible, and to determine therefrom the limits of running speeds which can be permitted.

To enable the analysis to be pursued on a basis similar to that in the Bridge Stress Committee's Report of 1928 to the Committee of the British Privy Council, a bridge oscillator is used to determine the actual frequencies of bridges under test. Cambridge stress recorders and deflectometers and latterly, S. R. 4 strain gauges, are used.

(*b*) *Responsibility.*

The responsibility for conducting bridge tests rests with the Bridge Assistant on each Region of British Railways and on the London Transport Executive, and with the Bridge Engineer on each railway within the India Railway Board. They are conducted by District Engineers on the Nizam's State Railway, India, and by the Research Section of the Civil Engineer's Department on the South African Railways.

(*c*) *Instruments.*

The main instruments used on bridge tests are set out in the following table :

(*d*) *Special stress and other investigations.*

None of the administrations reports having carried out systematic long term tests on bridges, other than the usual accurate measurement of key dimensions and levels to record trends in suspected distortions and settlements.

No application is reported, of recently developed methods whereby it is possible to determine the dead load stress actually being carried by a metal section of a bridge.

Dead loads carried by main tie bars of arch type roof principals have been determined on British Railways by transferring the load to temporary ties, and recording the relief of stress.

The Southern Region of British Railways has carried out loading tests and deflection recordings on a celluloid model of a bridge which is a redundant combination of a series of metal arch ribs and continuous plate girders. Analysis of the deformations of the model has led to the clarification of the distribution of live load in the bridge. Subsequent recordings of stress at critical sections of the bridge under load, has confirmed the accuracy of the analysis.

(*e*) *Comments.*

The South African Railways and Harbours is the only administration to report

	British Railways	India Railway Board	South African Railways
Stress recorders			
(i) Static or crawl tests .	Foster strain gauge.		
(ii) Crawl and dynamic tests	Fereday Palmer Cambridge	Fereday Palmer Plan to use resistance wire gauges.	Cambridge SR. 4 strain gauges.
Deflectometers	Cambridge Dial micrometers.	Direct recording pencil.	Cambridge.

special developments being pursued in the field of bridge testing. It is the policy of that administration to obtain with the maximum degree of accuracy, the magnitude of the various components of the total dynamic increment which is imposed on the several parts of bridges by the locomotives which they wish to use as widely as possible over their system. It is confirmed that more exact information shows that existing bridges can be permitted to carry heavier loading than has been permitted hitherto.

On the other hand British Railways propose to extend more widely their practice of analysing the load distribution in bridges by carrying out bridge tests, to obtain a more reliable basis for the assessment of their capacity, with less emphasis on a precise analysis of the dynamic increment of the live load.

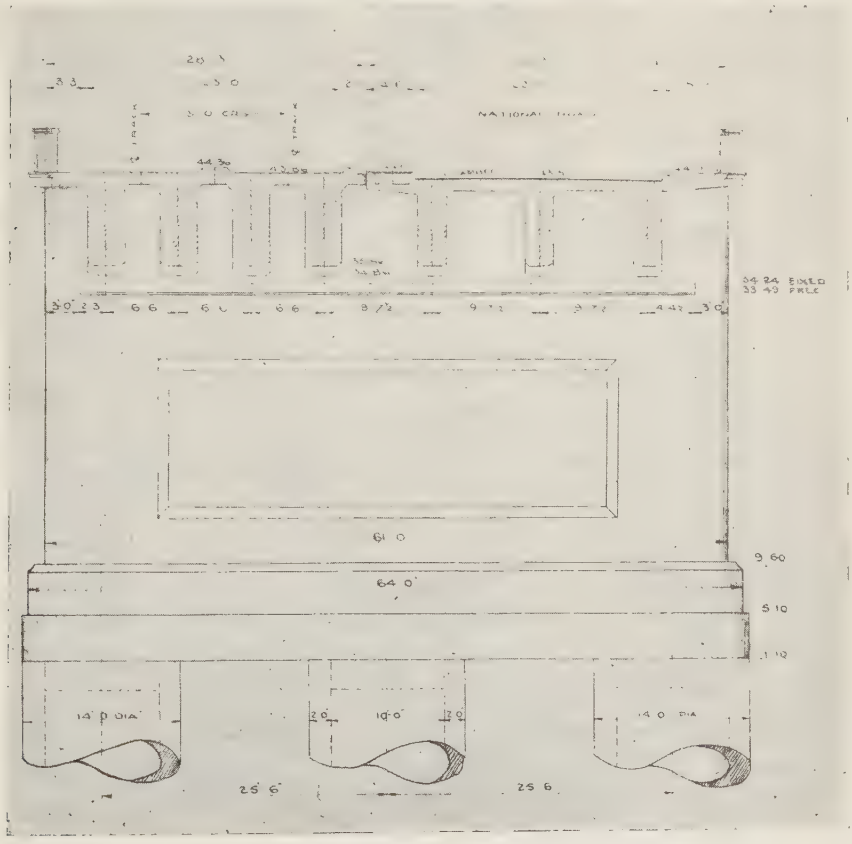


Plate 34. — South African Railways. Combined road and rail bridge over Umkomaas river. General layout.

PART II.

Results obtained in the construction of underbridges in reinforced concrete.

The Nizam's State Railway, India, and the Victorian Railways, Australia, report

that no reinforced concrete underbridges have been built on those systems.

1. *Retrospect.*

The earliest constructed reinforced concrete underbridge is reported by the Pennsylvania Railroad Company, comprising a simple span reinforced slab, built in 1910, and continuing in service up to the present time.

Other early bridges in this medium and still in service comprise a double track bridge of 41′ — 9″ span, consisting of T-beams and deck slab, with stiffening cross beams between the webs of the T-beams, on the London Transport Executive system; small 6-ft. spans on the India Railway Board's system, built about 1920, and a half through type bridge of 37′ 6″ span built in 1934 on the South African Railways.

Interesting reinforced concrete constructions are reported by the South African Railways and Harbours :

(*a*) *Umhlatuzi bridge.*

Comprises tied arches of 7 spans, 120-ft. centres of bearings. The arches are built to a parabolic profile, with a rise of 30-ft., that is, one quarter of span. The clear distance between ribs is 15-ft., and each span is divided into twelve bays of 10-ft. The arch ribs are 27″ thick, with a crown depth of 3′ 10″ and a haunch depth 5′ 10 1/2″.

(*b*) *Umkomaas bridge.*

Comprises a combined road and rail bridge carrying a road with a carriageway 22-ft. wide, and footwalks on each side, 4-ft. and 5-ft. wide respectively. The rail portion of the bridge carries two tracks at 13-ft. centres, on a deck 28-ft. wide. There are nine spans, each 81-ft. between centres of piers. Each track is carried by a pair of T-beams at 6′ 6″ centres. The roadway is carried on three T-beams at 9′ 7 1/2″ centres. Each pier is carried on three 14-ft. diameter reinforced concrete cylinders, all cylinders being sunk to rock or hard material. The pairs of beams each carrying railway track are completely separated by a longitudinal joint, and the roadway portion of the bridge is likewise separated from the railway portion. (See Plate 34.)

The London Midland and Scottish Railway — now the London Midland Region of British Railways — constructed a reinforced concrete underbridge comprising propped cantilever beams with a short suspended span, as shown on Plate 35.

2. *Reinforced concrete beam bridges.*

It is reported that standard types of reinforced concrete bridges have been developed as follow :

Administration	Type	Span range
British Railways (See Plate 36) .	Pre-cast slab units Pre-cast T-beam units	Spans 6′ 6″ to 31′ 6″ Spans 31′ 6″ to 40′ 0″
The Pennsylvania Railroad Cy.	Pre-cast slabs	Spans up to 32′ 0″
India Railway Board.	Slabs	Spans up to 15′ 0″
South African Railways and Harbours	T-beam construction	40′ 0″ span 60′ 0″ span

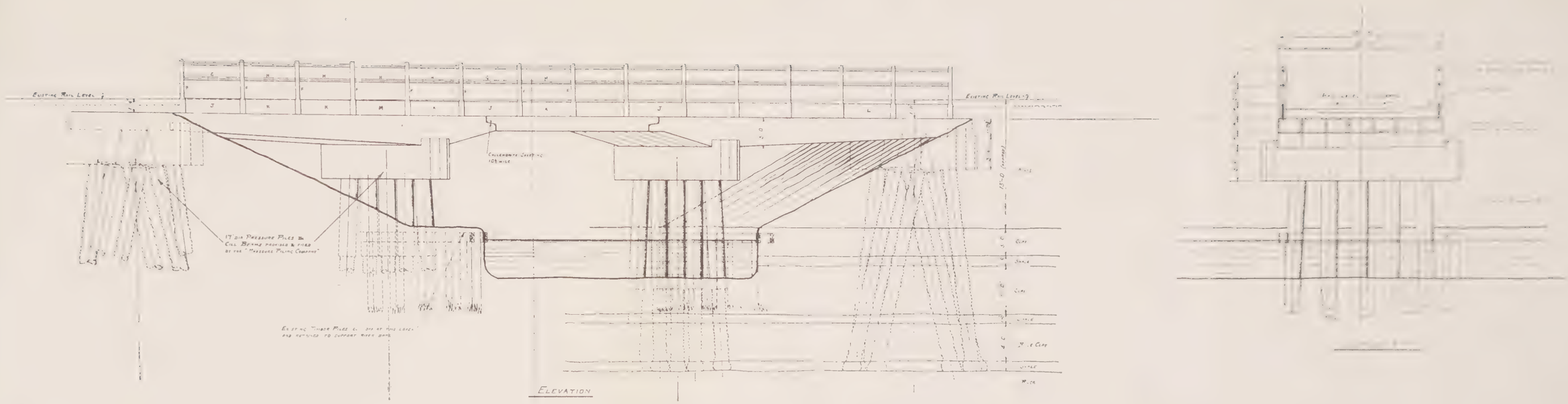


Plate 35. — British Railways (L. M. Region). — Beggarlee Branch bridge No. 1

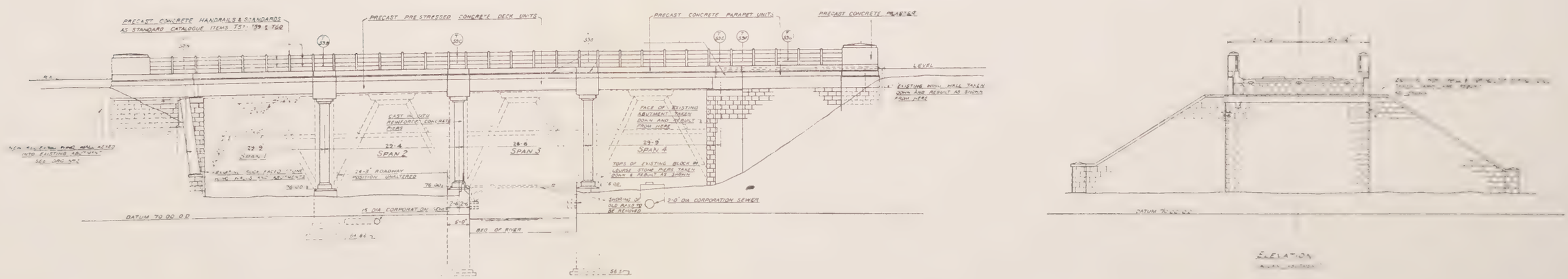

PRECAST CONCRETE HANDRAILS & STANDARDS AS STANDARD CATALOGUE ITEMS TS1, TS9 & T60
PRECAST PRESTRESSED CONCRETE DECK UNITS
PRECAST CONCRETE PARAPET UNITS
PRECAST CONCRETE PLASTERS
LEVEL
CAST IN SITU REINFORCED CONCRETE PIERS
SPAN 1
SPAN 2
SPAN 3
SPAN 4
24-3" ROADWAY POSITION UNALTERED
FACE OF EXISTING ABUTMENT TAKEN DOWN AND REBUILT FROM HERE
TOPS OF EXISTING BLOCK IN COURSE STONE PIERS TAKEN DOWN & REBUILT AS SHOWN
SHORING OF OLD MAIN TO BE REMOVED
2-0" DIA CORPORATION SEWER
DATUM TO OD OD
BED OF RIVER
ELEVATION
(FROM N.W.)

Plate 37. — British Railways (L. M. Region). — Lostock Junction to Pemberton line Bridge No 54.

ELEVATION A
ELEVATION B
BRICKWORK PARAPET REBUILT
TO MATCH EXISTING WING WALLS
PLAN

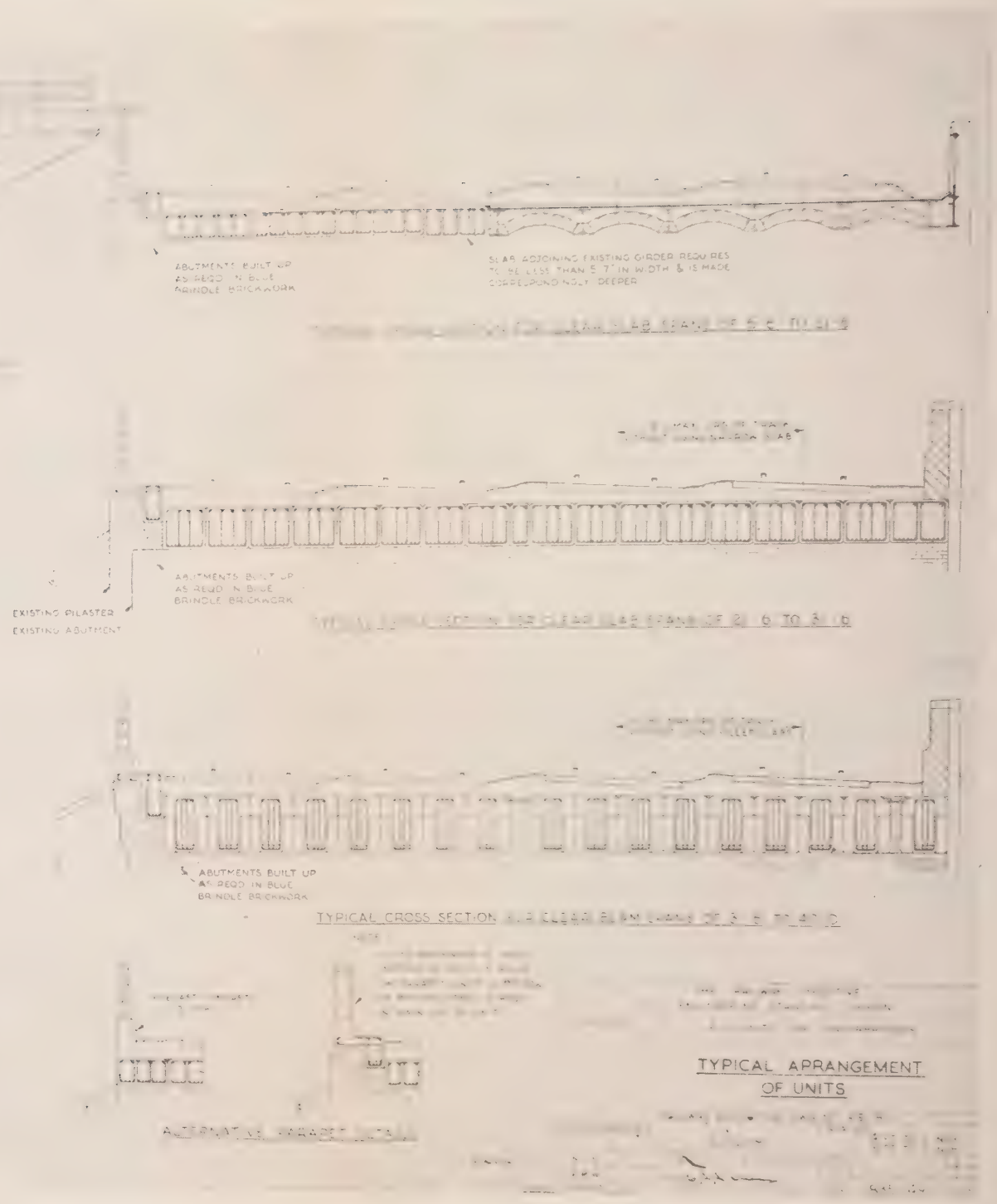

ABUTMENTS BUILT UP
AS REQD IN BLUE
BRINDLE BRICKWORK
SLAB ADJOINING EXISTING GIRDER REQUIRES
TO BE LESS THAN 5' 7" IN WIDTH & IS MADE
CORRESPONDINGLY DEEPER
ABUTMENTS BUILT UP
AS REQD IN BLUE
BRINDLE BRICKWORK
EXISTING PILASTER
EXISTING ABUTMENT
ABUTMENTS BUILT UP
AS REQD IN BLUE
BRINDLE BRICKWORK
TYPICAL APRANGEMENT
OF UNITS

Plate 36.

The maximum span for which simple beam type reinforced concrete construction is thought to be suitable and economical, ranges from 30-ft. to 45-ft. for rectangular section slabs, and from 40-ft. to 80-ft. for T-beams or beams of cellular form.

3. *Other forms of construction.*

The India Railway Board considers that the slab form of construction is only economical up to spans of 15-ft., and that longer span bridges should be either of the girder type or of the rigid frame type.

The South African Railways and Harbours has standard types of two-pinned rigid frame construction in reinforced concrete, suitable for underbridges of 50-ft span, at sites where the available construction depth is limited. Bridges of similar design, up to 60-ft. span have been built.

4. *Materials requirements.*

(*a*) Mild steel bars to the normal specifications, i. e. requiring 28 — 33 tons per square inch tensile strength, are generally used by the British, Indian and South African Railways. The Pennsylvania Railroad Company uses an intermediate grade steel with a minimum yield of 40 000 lbs. per square inch.

British Railways use hard drawn wire in the form of reinforcing fabric to British Standard Specification No. 785, and the India Railway Board uses at times high tensile steel to India Railways Standard Specification M. 23 and also hard drawn steel wire. The stress in such steel is limited to half the yield stress or a maximum of 27 000 lbs. per square inch.

Welding of reinforcement is permitted by British Railways, subject to careful supervision and planned locations of welds, and by the Pennsylvania Railroad Company, who adopt a reduced working stress in welded bars. The India Railway Board permits welded joints, also with locations carefully planned and staggered, such that they occur where the bar load does not exceed 75 % of the maximum, and not more than 50 % of the bar welds in a group of bars occur at one section. South African Railways permit welding of bars subject to compressive load.

Essential requirements for a good and satisfactory reinforcement assembly are simplicity, and avoidance of complicated stirrup arrangements, adequate spacing provided between adjacent bars, and the arrangement of the whole assembly into a rigid cage unit.

Neither British Railways nor the Pennsylvania Railroad Company considers that the use of high tensile steel reinforcement results in economy in normal reinforced concrete design. The India Railway Board considers there is a useful field for the use of high tensile steel, provided that the working stress is limited to 27 000 lbs. per square inch, to avoid undue cracking in the concrete, whilst South African Railways see no reason why it should not be used, provided that high tensile and mild steel bars are not mixed in the same assembly.

The minimum cover of concrete over reinforcement considered to be desirable for bridges varies from 1 1/2″ to 2″ by British Railways, 1/2″ to 2″, depending on the size of the bars, by the India Railway Board, and 1″ where dry atmospheric conditions prevail, to 2″ in the wetter coastal belt, by South African Railways.

(*b*) The proportions and requirements for concrete for bridges as reported, are as scheduled in Table 2.

Careful watch on varying qualities, grading, and water content of aggregates is necessary with close supervision and control of the mix, so that the highest quality of concrete is made in relation to the general proportions laid down. Specimens to be made at regular intervals and tested to confirm the consistency of the quality of the concrete being produced.

British Railways prefer the use of pre-cast reinforced concrete units manufactured under carefully controlled shop conditions.

Vibration of concrete in the construction of reinforced concrete is considered to be desirable by all the administrations which have reported, and that the concrete in all

TABLE 2.

	British Railways and L. T. E.	Pennsylvania Railroad Company	India Railway Board	South African Railways
Mix				
Cement	1	630 lbs.	1	1
Sand	2	1 370 lbs.	2	2
Coarse Aggregate. . .	4	1 740 lbs.	4	4
Water content				
Water/cement ratio . .		0.55	To give densest mix.	0.5 — 0.65
Slump.	Less than 3″	3″		2″ — 4″
Strength				
At 28 days	3000 lbs.	4 500 lbs.	As specified. (See Appendix 1)	—

parts which it is possible to arrange, should be vibrated, preferably using internal vibrators.

The Pennsylvania Railroad Company alone reports the introduction of special materials into concrete, and they have generally used an air entraining admixture to improve the workability and durability of the concrete. This has not been adopted for a sufficiently long period for any final conclusions to be drawn.

British Railways and the India Railway Board have used high alumina cement and ciment fondu on local repairs, where early strength has been necessary, but no administration reports having used special cements for actual bridge construction.

5. *Defects and their prevention.*

British Railways, the India Railway Board and South African Railways all report that cracking, followed by spalling, of concrete in bridges can be traced to faulty design, poor quality of concrete, or inadequate care given at the time of construction to the precise location of reinforcement. This has been most evident where the concrete has been subject to chemical action due to proximity to the sea or to being subject to blast from locomotives, or other corrosive conditions.

The Pennsylvania Railroad Company has experienced deterioration of concrete deck slabs due to freezing and thawing of poor concrete subject to brine drippings, generally where no waterproofing layer has been provided on the concrete.

Administrations agree that this is best safeguarded against in present day construction, particularly where severe weather conditions obtain, by care in design, in the control of the quality of the concrete, in the adoption of vibration, and in strict supervision of the placing of the concrete between the reinforcement and the bottom casing form. The Pennsylvania Railroad Company considers that the use of concrete with about 3 % entrained air appears to show best test results in obtaining resistance to freezing and thawing effects.

Repairs to defects have been carried out on British Railways by cutting out, wrapping with light mesh where possible and placing a new cover of cement mortar applied by air pressure gun.

6. *Design stresses.*

Design of reinforced concrete bridges has hitherto been based on the normally accepted principles of limiting working stresses in steel and concrete, calculated from the assumption that plane sections remain plane after bending, and with no tensile strength allowed for in the concrete. More recently developed plastic theories are being examined, particularly by the South African Railways, but no change from the above basis for design has yet been made.

The permissible stresses adopted are set out in Table 3.

Both British Railways and the India Railway Board consider that permissible stresses in concrete could be increased provided that close control of the concrete is ensured, and confirmed by consistent test results.

7. *Design loading.*

Provision is made for the dynamic increment of the live load in the design of reinforced concrete bridges, on the same basis as for metal bridges. The South African Railways make reduction from the full dynamic allowance, as for masonry bridges, in those cases where justified by the depth of fill and ballast between the underside of sleepers and the bridge deck.

The lateral width of bridge over which the live load is considered to be distributed is taken at 10-ft. on British Railways for the depth of ballast which it is normally possible to provide. A width equal to the sum of the sleeper length and the depth of fill and ballast is adopted by the India Railway Board, and a similar allowance according to the depth of fill and ballast is made by the South African Railways.

TABLE 3.

		British Railways and L. T. E.	Pennsylvania Railroad	India (*) Railway Board	South African Railways
Permissible stress		lbs./sq. inch.	lbs./sq. inch.	lbs./sq. inch.	lbs./sq. inch.
Concrete	bending compression	1 250		750 — 1 250	750 — 1 000
	shear. (diag. tens.)	125	A. E. R. A. Specification	75 — 125	75
	bond	150		100 — 150	—
Mild steel	Tension in beams	20 000		18 000	18 000
High tensile steel . .	Tension in beams			24 000	

(*) *Note.* The complete range of the India Railway Board permissible stresses in relation to mix and cylinder strength requirements of concrete, and for steel reinforcement are scheduled in Appendix II.

In the design of skew bridges, no reduction of bending moment by virtue of the skew, is allowed but in cases where the skew is heavy, the India Railway Board and the South African Railways report that the main reinforcement is arranged to lie normal to the line of the bridge supports, with a special arrangement of reinforcement appropriate for the loading of the triangular areas arising from the skew.

8. *Bearings.*

Few reinforced concrete beam type underbridges have been built comprising spans of such length as to require other than plain friction seatings on to abutments and piers. For medium spans, up to 80-ft. in some cases, flat metal bed plates have been provided. For longer spans, rocker and roller bearings are generally considered to be necessary. The South African Railways consider it wise to provide rocker and roller bearings where the span exceeds 50-ft.

No administration reports having made special determinations of coefficients of friction for various types of sliding and roller bearings as applied to reinforced concrete railway bridges.

9. *Framed constructions.*

The India Railway Board reports that the most successful form of construction other than the normal beam type, has comprised rigid frames, of about 40-ft. span, and they recommend that with such construction, hinges should be provided at foundation level to minimise the effects of settlement.

10. *Pre-cast units.*

British Railways, the Pennsylvania Railroad Company and the India Railway Board have all made use of pre-cast reinforced concrete bridges. This is the more usual practice for beam and slab type bridges on British Railways and the India Railway Board. It is considered that the depth of ballast normally overlying a bridge deck, comprising a series of pre-cast units, results in adequate distribution of the live load. Deflection tests carried out on British Railways have confirmed that such is the case. Where complete absence of any dripping of water through the meeting faces of pre-cast units is really necessary, it is the practice on British Railways to form rebates along the edges of slab units with projecting rods in some cases, the rebates being filled with concrete at site.

11. *Waterproofing.*

Waterproofing of decks of reinforced concrete bridges is not carried out by the India Railway Board, is done in the majority of cases by the Pennsylvania Railroad Company, and at locations where the nature of the roadway beneath justifies, by British Railways and South African Railways.

Membrane reinforced waterproofing layers, of asphaltic or bitumastic mediums, are used, protected from injury by stones or tools used for permanent way maintenance, by a layer of asphaltic concrete, or by suitably bedded tiles.

12. *Track and ballast.*

No case is reported where the tracks have been laid direct on to the concrete decks of reinforced concrete bridges, and such a practice is not considered to be desirable.

The minimum depth of ballast considered to be desirable is about 8″, with a minimum of 6″ where the track is superelevated due to curvature, although the India Railway Board prefers a depth of 12″, and the limiting construction depth which must be complied with so often on British Railways limits the depth of ballast in some cases to as little as 4″, in which cases stone not exceeding 1″ grading is generally used.

13. *General.*

For the smaller and medium spans of bridges the use of reinforced concrete construction, particulary in the form of simple slabs and beam units is considered to be satisfactory, and with improved

methods of production and control of high quality concrete, will continue. Their use in the future is bound to be governed by the results obtained from the use of pre-stressed concrete construction, and their relative economics and proved reliability in service.

The future use of reinforced concrete in constructions more suitable for longer span bridges, particularly on South African Railways will depend upon their experience of the behaviour of the more recently constructed bridges, carried out under special supervision.

***

PART III.

Pre-stressed concrete and its future possibilities.

The Pennsylvania Railroad Company, the Nizam's State Railway, India, the Sudan Railways and the Victorian Railways, Australia, make no report on this section, as no works in pre-stressed concrete have been constructed on their systems.

The South African Railways report that the administration has no experience of this type of construction and that under the conditions in that country, it does not seem likely to be adopted in the near future unless prices become competitive for pre-cast work and adequate supervision is available for « in situ » work.

1. *Type of anchorage.*

The Indian Railway Board reports that in the design of pre-stressed concrete bridges to carry railway tracks, they have adopted the system of pre-stressing which depends entirely on the end anchorages. This is considered to be the most satisfactory method, and facilitates the construction.

On British Railways designs have been developed in accordance with both the system in which the pre-stress force is developed solely by the bond of the wires in the concrete, and the system in which end anchorages are used. No firm requirement as to the adoption of either system is being laid down. For simple slab units, involving the casting of numbers of very similar beams, the system relying on bond may well be the more economical, and is likely to be adopted, whereas for longer spans and « in-situ » construction end enchorages would be used, with the wires grouted in after they have been tensioned. The incidence of the various patent rights associated with forms of end anchorage of the wires tends to add to the complexity of adopting that system.

2. *Type of wire.*

Both the India Railway Board and British Railways have used hitherto cold drawn high tensile steel wire, circular in section, 0.2 in. diameter, having a tensile strength of about 100-tons per square inch. During the process of tensioning, wires are stressed up to about 65 tons per square inch, and the long term working stress adopted is from 50 to 55 tons per square inch.

3. *Quality of concrete.*

The India Railway Board requires the concrete used for pre-stressed concrete construction to have a minimum cylinder strength of 3 600 lbs. per square inch at 28 days. The aggregates and water content are carefully proportioned round the nominal mix and production is under closely controlled workshop conditions.

A working compressive stress of 1 500 lbs. per square inch has been adopted up to the present time.

British Railways require the concrete for the construction of pre-stressed concrete units for bridges to have a compressive strength of 7 500 lbs. per square inch at 28 days, and proportioning and control under shop conditions is exercised to secure consistently high quality concrete.

A working compressive stress of about 2 000 lbs. per square inch is adopted.

Strictly limited tensile stress is permitted in the concrete at transfer of the pre-stress load, but in the case of underbridges, design is on the basis that no direct tensile

stresses will take place in the concrete under working conditions.

For road bridge construction, design is permitted on the basis of a limited range of tensile stress in the concrete.

4. *Bridges constructed.*

The India Railway Board has constructed 40-ft. and 60-ft. span underbridges, for metre gauge railway, each comprising a pair of pre-stressed concrete beams, 4′ 7″ and 6′ 1″ deep respectively, the timber sleepered track being laid direct on to the tops of the beams. No overbridges have been constructed in pre-stressed concrete.

The London, Midland and Scottish Railway (now British Railways) constructed a viaduct in 1946 comprising four spans of 27-ft. clear opening.

Each span consists of sixteen pre-stressed concrete beam units, which were constructed under carefully controlled workshop conditions, transported to the site by rail and placed in position by crane. (See Plate 37.)

The bond of the wires in the concrete is relied upon for the entire transfer of the pre-stress force in this construction.

A design is being developed at the present time on the Western Region of British Railways for the replacement of an existing viaduct in close proximity to the sea. (See Plate 38.)

Reconstruction of a series of road overbridges is being carried out by the Eastern Region of British Railways on a route where additional headroom over track level is necessary to provide for the installation of overhead electrical traction conductors. Pre-stressed concrete I-beam units are being used, manufactured under shop conditions, and including a proportion of non pre-stressed wires. The clear openings for which this type of construction is being adopted range from 21 ft. to 32 ft. The pre-stressed units are placed side by side to give a continuous soffit across the width of the bridge and thereafter the construction is completed into a composite slab by placing in situ concrete to the requisite level. (See Plate 39.) The bond of the wires in the concrete is relied upon for the entire transfer of the pre-stress force in this construction.

Plate 38. — Barmouth. — Old Chapel viaduct.

Designs are being developed on British Railways for the reconstruction of road overbridges involving pre-stressed concrete slab units with wires positively anchored at the ends, and type designs of pre-stressed concrete slab units for underbridges ar

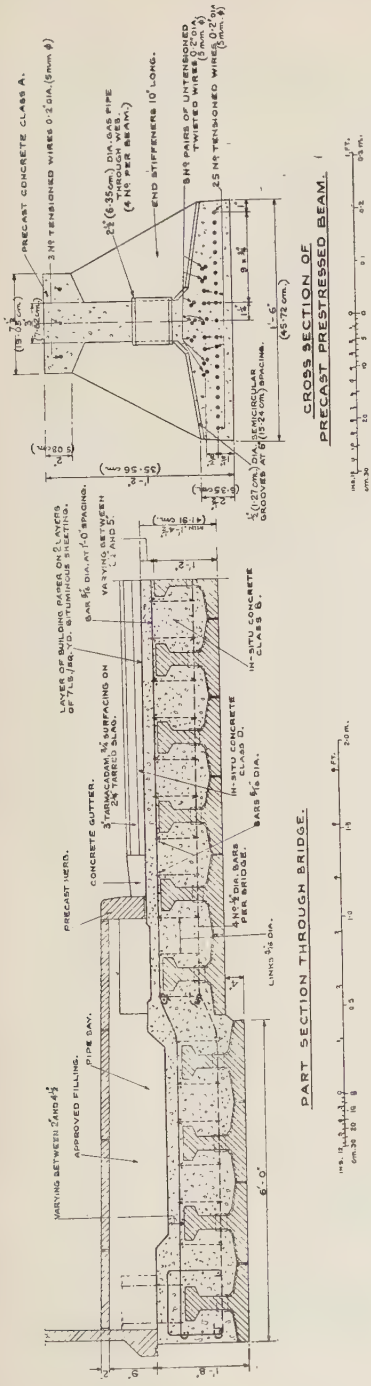


Plate 39. — British Railways (Eastern Region). — Details of decking and prestressed concrete beam for overbridges.

being developed. A typical design is shown on Plates 40 and 41, of which the first was put into service in January, 1950.

5. *Sequence of pre-stressing.*

The India Railway Board considers that the sequence of construction most likely to be developed in the future will be for the beams to be pre-fabricated at works, either non pre-stressed or only partially pre-stressed with assembly and final pre-stressing at the site. It is considered that by this means the quality of concrete will best be ensured and that there is advantage in arranging for pre-stressing to be done in final position or in a position from which the construction is readily lowered into final position.

On British Railways, where the main use of pre-stressed construction is likely to be in the replacement of existing bridges under site conditions which severely limit the interval between removal of an existing bridge, and the availability of a new bridge to carry traffic, it is probable that complete construction and pre-stressing of units at works must be the practice most widely adopted in the future for the normal range of spans, and available construction depths.

Each work where more freedom of choice exists will be studied on the merits of the case.

Manufacture of the concrete units under shop conditions is considered at the present time to be most valuable, giving means for better control and supervision of the quality of concrete and the workmanship.

6. *Special application.*

The Eastern Region of British Railways has applied pre-stressing to the construction of the main bearing beams of a bridge, of which the level has been raised. Pre-cast concrete sections of the beam were placed and subsequently pre-stressed to form a single distributing beam.

Similar applications are likely to be of considerable use under difficult site conditions in special cases in the future.

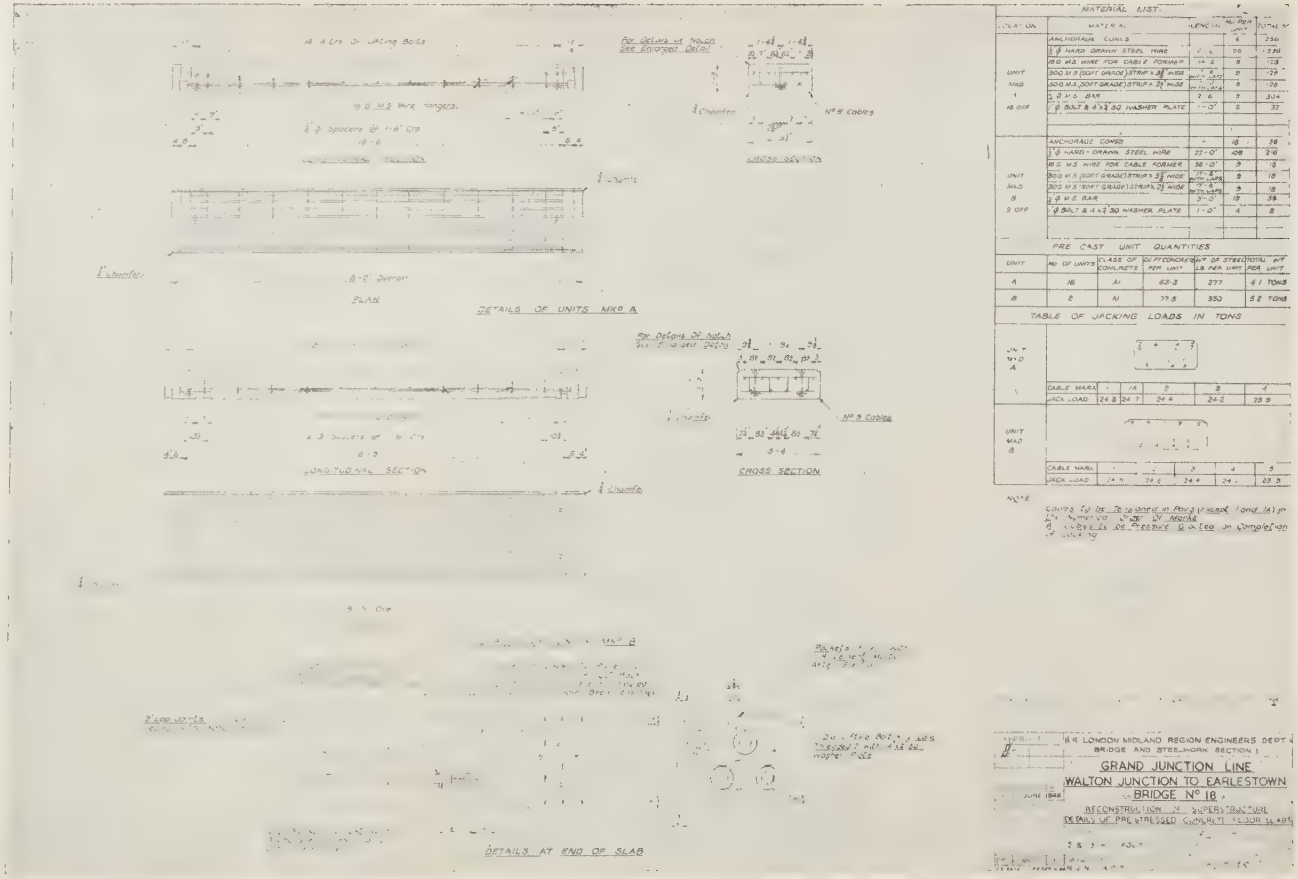

MATERIAL LIST.
PRE CAST UNIT QUANTITIES
TABLE OF JACKING LOADS IN TONS
PLAN
DETAILS OF UNITS MKS A
CROSS SECTION
DETAILS AT END OF SLAB
BR LONDON MIDLAND REGION ENGINEERS DEPT
BRIDGE AND STEELWORK SECTION
GRAND JUNCTION LINE
WALTON JUNCTION TO EARLESTOWN
BRIDGE No 18
RECONSTRUCTION OF SUPERSTRUCTURE
DETAILS OF PRESTRESSED CONCRETE FLOOR SLABS

Plate 40.

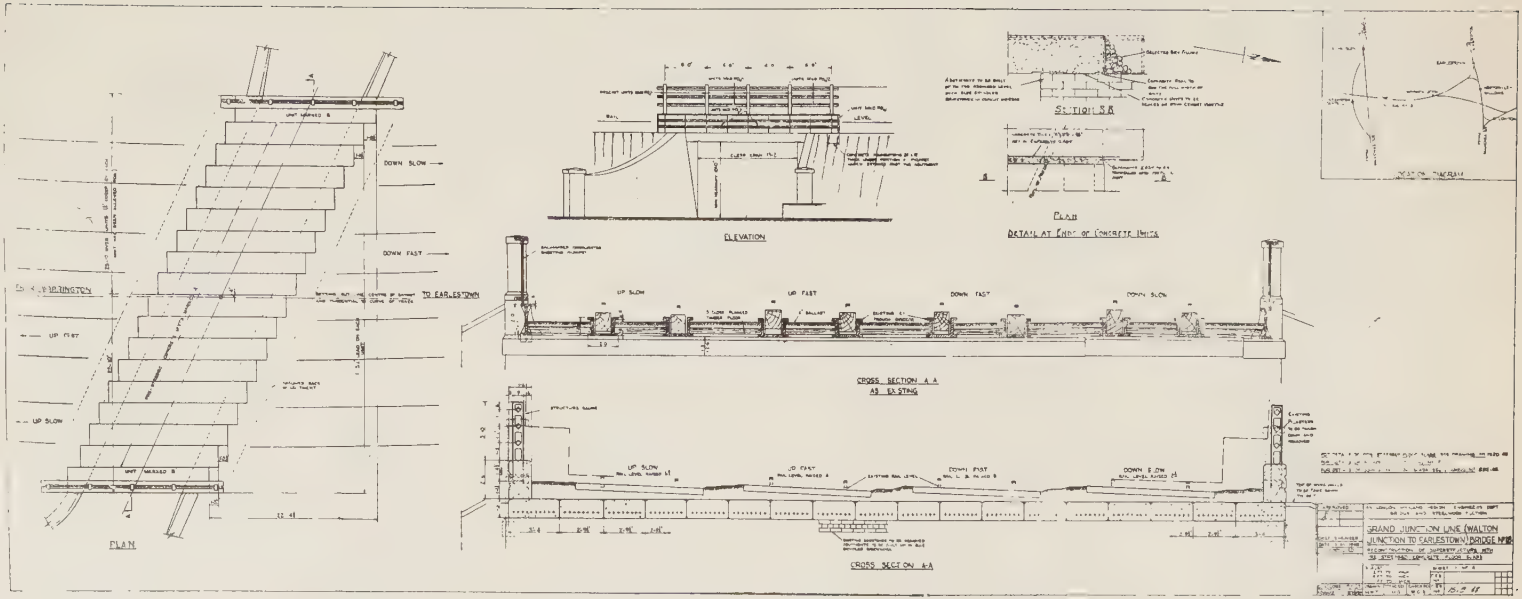

DOWN SLOW
DOWN FAST
UP FAST
UP SLOW
TO EARLESTOWN
PLAN
ELEVATION
SECTION S.B.
PLAN
DETAIL AT END OF CONCRETE LINING
UP SLOW
UP FAST
DOWN FAST
DOWN SLOW
CROSS SECTION A A
AS EXISTING
CROSS SECTION A-A
GRAND JUNCTION LINE (WALTON
JUNCTION TO EARLESTOWN) BRIDGE No

Plate 41.

The possibilities of applying pre-stressing to concrete units to be incorporated with essentially metal decks of bridges is being explored by British Railways at the present time, with the object of producing a composite construction in which the concrete shall be entirely free from cracking in service.

7. *Various applications.*

Both the India Railway Board and British Railways are of the opinion that there will be a useful field of application in the future, for the use of pre-stressed beams in place of steel joists in construction, and also for the use of flexible pre-stressed units as reinforcing elements for concrete slabs. The type of overbridge now being built by the Eastern Region of British Railways is an application of a combination of these two forms of construction.

It is also considered that there will be a useful field for the assembly of pre-stressed elements to form built up units as in metal construction.

The India Railway Board is considering adopting pre-stressed concrete for the construction of tanks, frameworks and for the manufacture of beam units for roofs, etc. On British Railways designs have been developed for pre-stressed concrete pylons and cross beams for the construction of portal frames for clearance gauges for use at level crossings over lines electrified on the overhead system. Pre-stressed concrete construction is being adopted in the design of a circular foundation beam for the race rail of an articulated type of turntable, and its use as a medium of construction for the main supporting framework of steam locomotive shed roofs is being investigated.

British Railways also report that pre-stressed concrete beam units for bridges have been made in which a number of the wires have not been pre-stressed, and therefore act in respect of the live loading, as normal reinforcement.

Both the India Railway Board and British Railways consider that in some cases this may prove to be an economical type, whereby a substantial margin of strength against ultimate failure can be obtained with the minimum number of pre-stressed wires and minimum sectional area of pre-stressed concrete.

8. *Waterproofing.*

Where a bridge deck comprises one pre-stressed concrete unit it is considered that waterproofing need not be provided. Where joints occur as in the case of a bridge comprising separate pre-stressed beam units laid side by side, unless lateral post-stressing is carried out, waterproofing will be necessary.

It is not considered that there is an inherent need to waterproof pre-stressed concrete for its own sake.

9. *Shrinkage and creep.*

The India Railway Board design on the basis of a shrinkage of .00025 and a creep of .0005. On British Railways it is usual to design on the basis of a 15 % — 20 % loss of pre-stressing load in the wires due to shrinkage and creep.

10. *Effect of dynamic loading*

Whilst there does not as yet exist any long term experience of the behaviour of pre-stressed concrete bridges, which have been subject to a very big number of loadings, it is considered that railway underbridges will be satisfactory, if designed to avoid any tensile stress occurring in the concrete.

This is supported by the somewhat limited results of repeated loading tests which have been carried out up to the present date on pre-stressed concrete units.

No adjustements to the limits of permitted stress have therefore been made hitherto in relation to the range of stress which will take place in service.

11. *Cement.*

Neither the India Railway Board nor

British Railways have used cement other than normal Portland or rapid hardening cement for pre-stressed concrete construction.

12. *Special methods and materials.*

Neither the India Railway Board nor British Railways report having carried out pre-stressing of concrete other than by wires tensioned with jacks.

The India Railway Board reports that the principle of pre-stressing has been applied to steel lattice girders to relieve the deformation stresses.

13. *Cost.*

The India Railway Board reports that at the present early stage in the development of its use, the cost of pre-stressed concrete is almost equal to the cost of steel for the construction of railway underbridges.

British Railways report that the cost of pre-stressed concrete construction for bridges is competitive, and in some cases is less costly than construction in steel or reinforced concrete and that if the subsequent maintenance costs are as low as it is reasonable to expect, the true economic comparison will in some cases decidedly favour the use of pre-stressed concrete.

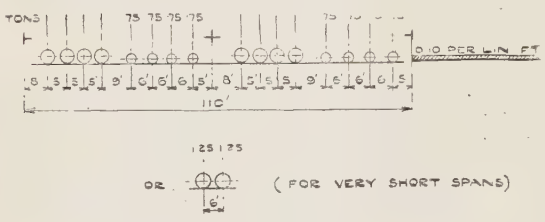
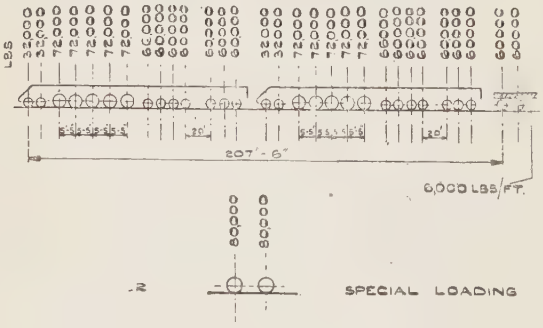
14. *General comments.*

Both the India Railway Board and British Railways consider that it is early in the era of pre-stressed concrete to pronounce from experience of actual constructions on the value of pre-stressed concrete, particularly for the construction of railway underbridges.

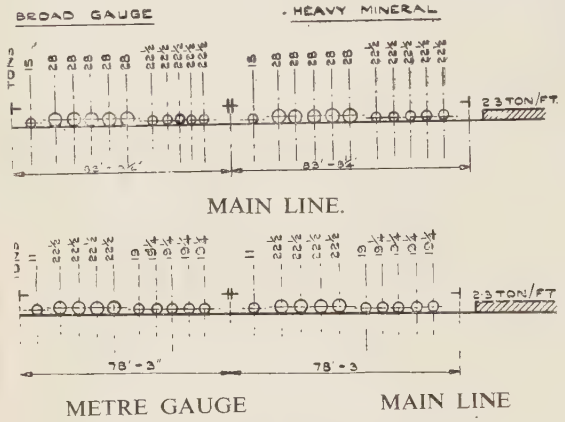
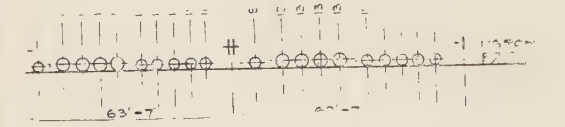
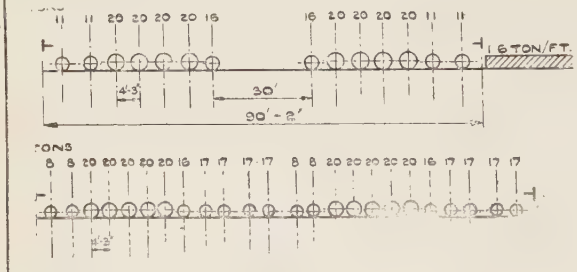
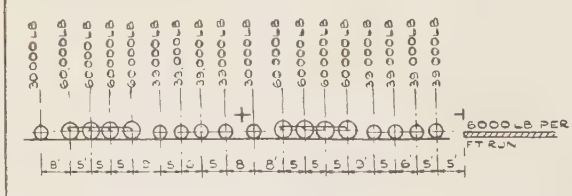
The advantage foreseen is low cost of maintenance of pre-stressed concrete constructions. Its application to bridge construction may be limited under certain conditions by inadequate site facilities or difficulty in the transport of beams made in concrete production shops.

Opportunities are foreseen by both administrations for the use of pre-stressed concrete construction and it may be a medium which will solve economically some of the problems arising from limited construction depth for bridges on British Railways where designs are well advanced for underbridges comprising pre-stressed concrete decks with welded plate main girders.

The India Railway Board foresee development in the use of pre-stressed concrete construction for frameworks and tanks, and for beams in shell type roofs.

Administration	Standard train loading	Basis for impact allowance
British Railw. The Railway Executive	BRITISH STANDARD UNIT LOAD 	Loading B. S. Units / Impact Component / Speed revo per sec 6.0 / 4.5 20 Whole engine hammer blow . . . . . tons 7.2 tons 4.0 16 Whole engine hammer blow . . . . . tons 18.0 tons 10.12 Effect of dynamic magnification d resonance is added.
London Transport Executive	Loading varied according to : *a* Tube lines only; *b* Electric multiple unit and goods engines; *c* Electric locomotives; *d* Steam locomotives.	Rail joint effect (Concentrated load per track) tons 6 tons 3.38 Lurching (addition or substraction from normal wheel loads) . . % 25 % 18 3
The Pennsylvania Railroad Company		*Stresses of one kind only.* Impact allowance = KL $K = \frac{300}{300 + S} \times \frac{L}{L + D}$ S = Loaded length for max. stress. L = Max. live load stress. D = Dead load stress. *Members subject to reversal of stress.* $K = \frac{300}{300 + S} \times \left(1 + \frac{m}{2M}\right)$ M = Max. dead + live load stress where *m* = Max. dead + live load stress w is of opposite sign and greater load stress.

Wind loading	Braking and traction forces	Lateral forces other than centrifugal forces
B. S. S. 153	*B. S. S.* 153	*B . S. S* 153
ally a wind pressure of 30 lbs. per ft. is used, but the pressure can derived from	Braking : 15 % of live load without impact.	A single force of 10 tons applied at rail level.
.003V^2. P = pressure lbs./sq. ft.		
= Velocity M. P. H. ssure on the bridge to be evaluated.		
ngth in ft. × a height of 12 ft.	Traction : 25 % of weight on driving wheels without impact.	
ditional exposure of windward ler and deck construction.		
lf of the additional exposure of the vard girder above or below the ght of 12 ft.		
A. R. E. A. specification	*A. R. E. A. specification*	*A. R. E. A. specification*
ded bridge :	Braking : 15 % of live load without impact.	A single force of 20 000 lbs. applied at the top of the rail.
lbs. per linear foot of the moving n;		
bs./sq. foot on exposed girders or ses.	Traction : 25 % of live load without impact.	
o be less than 200 lbs. per linear t for loaded chord or flange, and lbs. per linear foot for the unload-		
loaded bridge : s./sq. ft. on the surface.		

Administration	Standard train loading	Basis for impact allowance
India Railway Board		*Broad gauge and metre gauge railway* Single track bridges : $I = \frac{65}{45 + L}$ ($\geqslant 1.00$) Double track bridges (two girders) : $I = 0.72 \times \frac{65}{45 + L}$ ($\geqslant 0.72$) Multi track bridges (interm. girders) : $I = 0.6 \times \frac{65}{45 + L}$ ($\geqslant 0.6$) Cross girders (two or more tracks) : $I = 0.72 \times \frac{65}{45 + L}$ Where L = loaded length.
Nizam's State Railway		
South African Railways and Harbours		Based on Bridge Stress Committee report. Similar to British Railways.
Sudan Railways	17 units B. S. loading.	$I = \frac{65}{45 + L}$
Victorian Railways Australia		Under review — developing on lines based Bridge Stress Committee report 1928.

(*Continued*)

Wind loading	Braking and traction forces	Lateral forces other than centrifugal forces
India-Bridge rules ressures are tabulated, with pro- ı to increase or reduce in certain led bridge — area to be taken as : zontal projected area of moving :e area of span above or below noving load.)aded bridge — area to be taken ice horizontal projected area.	*India-Bridge rules* Braking and tractive forces to be provided for when construction permits dispersal are scheduled for broad and metre gauge and prevailing types of traffic. e. g. Broad Gauge. Loaded length: 40 / 70 / 100 / 200 Braking-tons: 16.6 / 27.2 / 35.7 / 54.1 Traction-tons: 22.7 / 31.5 / 37.8 / 37.8	*India-Bridge rules* Lateral bracings of the loaded deck of railway spans shall be designed to resist in addition to wind and centrifugal loads a lateral load due to racking forces of 400 lbs. per linear foot treated as a moving load.
B. S. S. 153	*B. S. S.* 153	*B. S. S.* 153
per sq. ft. on total area.		

India Railway Board. — Permissible stresses in concrete reinforcement. APPENDIX II

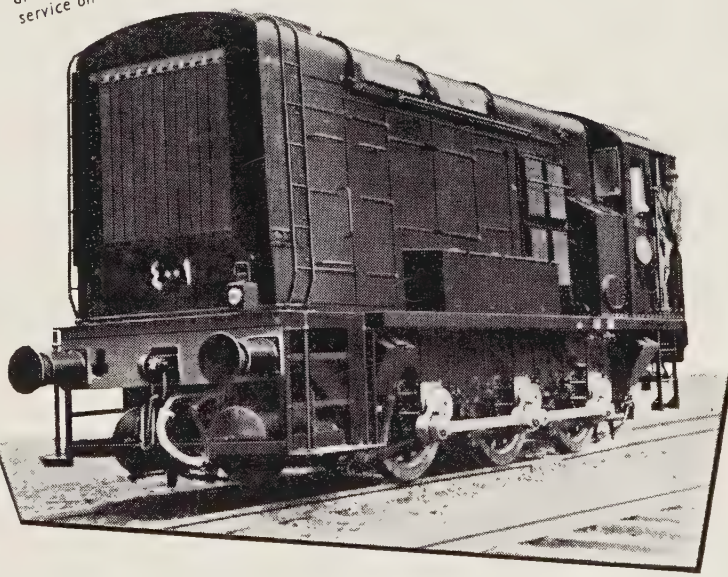
—	Mix ref.	Nominal mix.	Proportions : c. ft. of aggregate per 112 lbs. bag of cement		Minimum cylinder strength requirements at 28 days and 7 days lb. per sq. in.			Modular-ratio	Permissible concrete stresses lb. per sq. in.			
			Fine	Coarse	Prelimi-nary tests 28 days 3.6x	Works tests 28 days 2.4x	Works tests 7 days 1.6x	40000	Bending	Direct	Shear	Bond
								3x	x	0.8x	0.1x	0.1x+25
1. *Ordinary grade concrete.*	I	1 : 1 : 2	1 1/4	2 1/2	3 510	2 340	1 560	14	975	780	98	123
	II	1 : 1.2 : 2.4	1 1/2	3 1/2	3 330	2 220	1 480	14	925	740	93	118
	III	1 : 1.5 : 3	1 7/8	3 3/4	3 060	2 040	1 360	16	850	680	85	110
	IV	1 : 2 : 4	2 1/2	5	2 700	1 800	1 200	18	750	600	75	100
2. *High grade concrete*	I	1 : 1 : 2	1 1/4	2 1/2	4 500	3 000	2 000	11	1 250	1 000	125	150
	II	1 : 1.2 : 2.4	1 1/2	3	4 320	2 880	1 920	11	1 200	960	120	145
	III	1 : 1.5 : 3	1 7/8	3 3/4	3 960	2 640	1 760	12	1 100	880	110	135
	IV	1 : 2 : 4	2 1/2	5	3 420	2 280	1 520	14	950	760	95	120

NOTE : (1) The tabulated values of the modular ratios are given to the nearest whole number; nevertheless, more exact values calculated from the formula 40 000/3x, may be used.
(2) If rapid-hardening cement is used, the strength specified above for seven days test shall be attained at three days.

No.	Designation of stress in steel reinforcement	Maximum permissible stresses in lb per sq. in.	
		Mild steel	Hard tensile steel or hard drawn wire
1	Tension other than in helical reinforcement in a column	18 000	24 000
2	Tension in helical reinforcement in a column	13 500	18 000
3	Compression in longitudinal reinforcement in columns	13 500	18 000
4	Longitudinal compression in a beam where the compressive resistance of concrete is not taken into account	18 000	24 000
5	Longitudinal compression in a beam where the compressive resistance of the concrete is taken into account	The calculated compressive stress in the surrounding concrete multiplied by the	

'ENGLISH ELECTRIC'

One of fifteen "English Electric" 350 h.p. diesel-electric shunting locomotives in service on the Egyptian State Railways.



diesel-electric shunting locomotives - - -

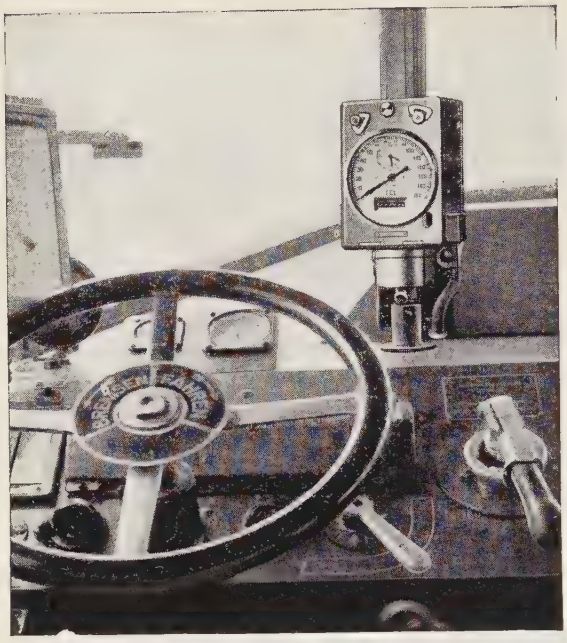
proved in service on British Railways and in four continents

Pioneers in Electric and Diesel-electric traction

THE **ENGLISH ELECTRIC** COMPANY LTD.

TRACTION DEPARTMENT - - - BRADFORD

Works: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

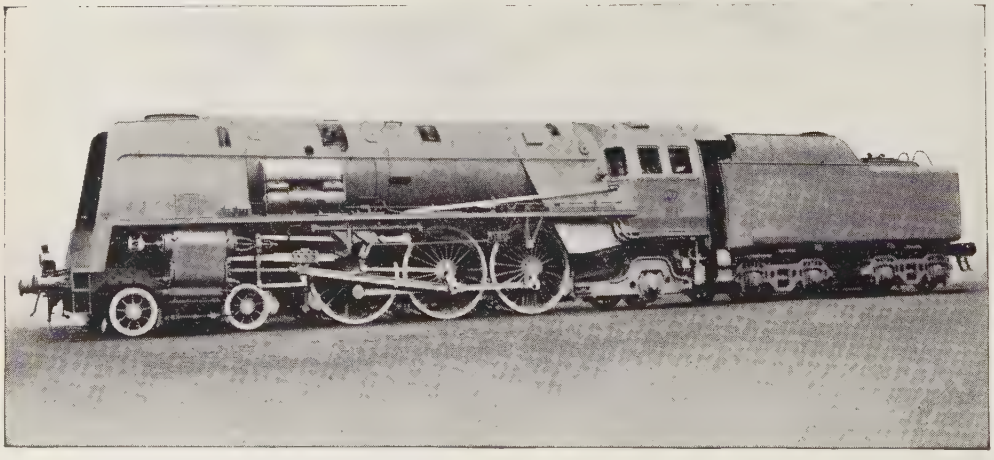


The TELOC Speed Indicators and Recorders

are the product of experience since 1887 in the construction of speed indicators and recorders for railway locomotives and vehicles.
The new type TELOC indicates the speed, the total distance travelled, the time of day. It records on the chart the speed, distance travelled, the time in hours and minutes and the time and duration of stops. If required the instruments can also be fitted with apparatus to record the pressure in the brake pipes, the direction of travel and the passing of signals, etc.

Hasler SA Berne
MANUFACTURE D'APPAREILS TÉLÉPHONIQUES ET DE PRÉCISION
FONDÉE EN 1852 TÉLÉPHONE NO. 64

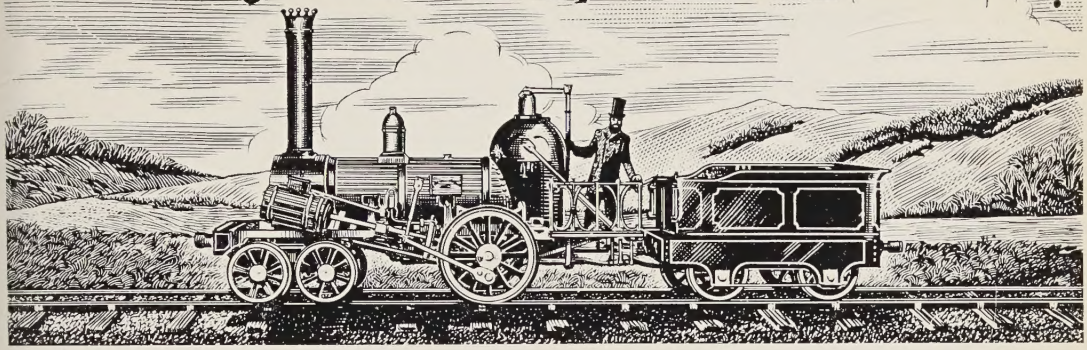
JOHN COCKERILL S. A.
SERAING (Belgium)



METALLURGY

MACHINERY and METAL STRUCTURES
SHIPYARD AT HOBOKEN (ANTWERP)

in the days before Superheated Steam!



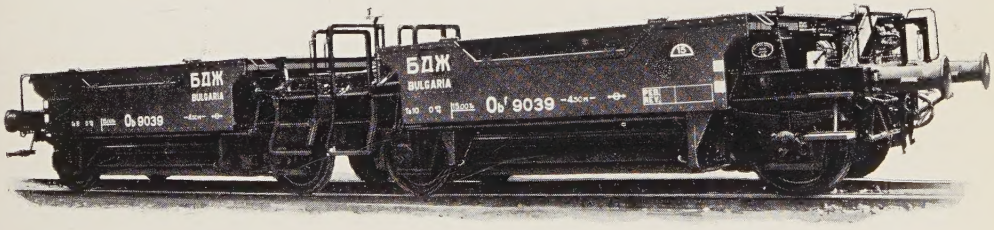
It is left to conjecture what might have happened if the modern steam superheater could have been fitted to locomotives of the early 1800's.

In modern locomotive design there is no doubt—the superheater is indispensable—in fact the British Railways' "Mallard" No. 60022, holding the world's speed record, is fitted with a

M.L.S.Co SUPERHEATER

The **SUPERHEATER** *Company Ltd*

53 HAYMARKET, LONDON, S.W.1
Works: TRAFFORD PARK, MANCHESTER 17



40 T. BOGIE BALLAST WAGON. LOAD 30 T. CAPACITY 33 CU. YD

ADVANTAGES OF AUTOMATIC BALLASTING

NO BLOCKADE OF SECTIONS - NO DISLOCATION OF THE REGULAR TRAIN SERVICES - REDUCTION OF EXPENSES

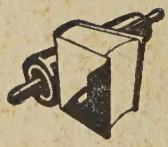
Further we supply :

ORIGINAL « TALBOT » SELFDISCHARGER HOPPER WAGON PASSENGER COACHES - GOODS WAGONS - DIESEL RAIL-CARS - ALL KIND OF SPECIAL WAGONS FOR MINING AND METALLURGICAL INDUSTRIES

WAGGONFABRIK TALBOT, AACHEN (GERMANY)

Alphabetical Index of Advertisers

Firms :		Specialities :
Anglo-Franco-Belge des Ateliers de La Croyère, Seneffe et Godarville (Soc.)	IV	Locomotives and railway rolling stock.
Ansaldo	—	Steam, diesel and electric locomotives.
Armstrong Oiler Co., Ltd. (The)	—	Lubricators.
Ateliers de Construction Oerlikon	—	Electrical equipment for all traction requirements.
Ateliers Métallurgiques (Les)	—	Locomotives and railway rolling stock.
Belgian National Railways	—	Passenger and freight services.
Bell Punch C°, Ltd.	—	Ticket issuing machines.
Brown, Boveri & C°, Ltd.	—	Electric locomotives.
Brugeoise et Nicaise & Delcuve	VII	Railway rolling stock and fixed equipment.
Bureau de Représentations J. Trachet	—	Anticorrosive bandages.
Cockerill (John)	XI	Machinery and metal structures.
English Electric, Ltd. (The)	X	Railway electrification.
Ferguson Ltd.	—	Tractors.
Firth (Thos) & Brown (John), Ltd.	—	Railway forgings and tools.
Forges de Courcelles-Centre (S. A.)	—	Draw gear, forged ironwork.
Gresham & Craven, Ltd.	—	Locomotive injectors.
Hasler (A. G.)	XI	Speed indicators and recorders.
Imperial Chemical Industries Limited	—	Boiler feedwater treatment.
Isothermos (Société générale)	III	Axleboxes.
Matisa Equipment Limited	VIII	Permanent way equipment.
Pieux Franki	—	Concrete railway sleepers.
S. A. B. (Svenska Aktiebolaget Broms-regulator)	VI	Automatic slack-adjusters.
Siderur (Société Commerciale de Sidérurgie)	IX	Rails, sleepers.
S. K. F. (Société Belge des Roulements à Billes)	V	Axleboxes.
Superheater Company (The)	XII	Superheaters for locomotives.
Usines Emile Henricot	—	Automatic couplers; steel castings for railway rolli stock.
Waggonfabrik Talbot	XII	Railway rolling stock.
Westinghouse Brake & Signal C°, Ltd.	II	Railway signaling. Brakes.
Winn & Coales Ltd.	—	Anticorrosive bandages.



M. WEISSENBRUCH & Co. Ltd.
Printer to the King.
(Manag. Dir.: P. de Weissenbruch,
238, chaussée de Vleurgat, XL.)

Edit. responsible : P. Ghilain
108, rue Général Gratry, Schaerbeek.

PRINTED IN BELGIUM